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Digital Mapping, Charting, and Geodesy Analysis Program Technical Review of Vector Smart Map Prototypes 1 and 2

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13. ABSTRACT *(Maximum 200 words)*

Currently under development by the Defense Mapping Agency (DMA), the Vector Smart Map (V_{Map}) represents a significant step forward in digital mapping. This Vector Product Format (VPF) relational database is intended to digitally represent map sheets (e.g., Joint Operational Graphics and Topographic Line Maps) at medium (Level 1) and high (Level 2) resolutions. In an effort to optimize Naval (meaning U.S. Navy and Marine Corps) usage of such data, the Digital Mapping, Charting, and Geodesy Analysis Program (DMAP) has evaluated V_{Map} Prototypes 1 and 2 and has suggested modifications. The review of Prototype 1 consists mainly of a comparison with a similar DMA product, namely Digital Feature Analysis Data, which contains features that are missing from the V_{Map} prototype. DMAP recommends the inclusion of these features in V_{Map}. In Prototype 2, DMAP discovered multiple quality control errors, which were found by viewing data around Texas and Bolivia. Comparisons with another VPF product, Interim Terrain Data, led to the discovery of even more V_{Map} inconsistencies. DMAP recommends that V_{Map} remain in the prototype stage until all errors are rectified.

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CONTENTS

DIGITAL MAPPING, CHARTING, AND GEODESY ANALYSIS PROGRAM
TECHNICAL REVIEW OF VECTOR SMART MAP PROTOTYPES 1 AND 2

1.0 INTRODUCTION

Vector Smart Map (V_{Map}), a Vector Product Format (VPF) relational database under development by the Defense Mapping Agency (DMA), is intended for digital implementation of medium (level 1) and high (level 2) resolution map sources. These implementations are designed to be a source of geographic data for Geographic Information Systems (GIS). To date, two prototypes have been developed and analyzed by the Naval Research Laboratory's (NRL) Digital Mapping, Charting and Geodesy Analysis Program (DMAP). Prototype 1, as defined by [1] and [2], is reviewed here in relation to another DMA product, Digital Feature Analysis Data (DFAD), since both have similar map sources. Particular attention is given to database content and accuracy requirements. For Prototype 2 ([3] and [4]), a much more thorough evaluation is given. In addition to a comparison with another VPF product, parts of the database were loaded into a relational database management system (RDBMS) to test VMap's capability with such systems.

2.0 PROTOTYPE 1

2.1 Content

V_{Map} consists of a high and low resolution library for each area, as well as a global reference library. The high and low resolution libraries contain the chart data divided into ten thematic layers:

(1)	Boundaries	(6)	Physiography
(2)	Data Quality	(7)	Population
(3)	Elevation	(8)	Transportation
(4)	Hydrography	(9)	Utilities
(5)	Industry	(10)	Vegetation

The Reference library contains the following five thematic layers:

(1)	Database Reference	(4)	Map Reference
(2)	Political Entities	(5)	Place Names
(3)	Tile Index		

2.2 Suggestions

Based on the existing database content as detailed in the V_{Map} high and medium resolution product specifications, and the reviewed prototype on Compact Disc Read-Only Memory (CDROM), DMAP makes the following comments and suggestions:

1. The V_{Map} medium chart accuracy requirements are "to be decided." DMAP recommends retaining at a minimum the DFAD Level 1 requirements of 130 m for horizontal and 10 m for vertical for heights ≥ 46 m.
2. The horizontal accuracy requirement for the high resolution 1:100,000 chart is given as 93 m, while the horizontal accuracy of the source chart is given as 14 m. This 79-m loss in accuracy is unacceptable for virtually all Naval applications and should be lowered.
3. A "Bridge Superstructure" feature should be added to the Transportation thematic layer with the following possible attributes: General, Suspension, Tower Suspension, Cantilever, Arch, Truss, Moveable Span, Bridge Towers.
4. An attribute describing bridge type should be added to the feature "Bridge" with the following possibilities: General, Suspension, Cantilever, Arch, Truss, Movable Span, Deck.
5. Railroad Yards/Sidings should have an attribute to describe its activity (empty, light, heavy).
6. The NAVAIDS (Navigational Aids) Aeronautical feature (1R030) is missing from the Transportation layer of the high resolution library.
7. Table 1 shows features contained in the DFAD Level 1 and Level 2 product specification that are not contained in the high or medium resolution V_{Map} specifications. They are listed according to the V_{Map} thematic layer in which they should be placed.

Table 1. DFAD Level 1 and Level 2 Product Specifications Not Contained in V_{Map} Specifications

Thematic Layer	Feature
Industry	Offshore Platform, Mine Shaft Superstructure, Blast Furnace, Refinery, Catalytic Cracker, Hopper, Dredge/Power Shovel/Drag Line, Storage and Repair Building, Offshore Loading Facility, Engine Test Cells
Utilities	Solar Energy Electrical Collection Panels, Solar Energy Heat Collection Panels
Transportation	Railroad Terminal, Railroad Station, Railroad Control Tower, Electrified Railroad Gantries/Pylons, Airport Control Tower, Airport Approach Lights Framework, GCA Facility, Motor Pool, Ship Storage Area/Ship Yard, Tunnel Entrance/Exit, Radar Antenna

Thematic Layer	Feature
Population	Grand Stand, Amusement Park, Display Signs (General), Billboards, Scoreboard, Overhead Highway Sign, Stockyard/Holding Pen, Observation Tower, Tower on Structure, Athletic Field Lights, Steeple, Navigation Light Ship, Depot
Physiography	Permanent Snow Field

8. Throughout the DFAD specification, buildings are categorized according to their roof types. V_{Map} has no feature attribute for roof type in the high or medium resolution libraries. An attribute for roof type should be added to Building in the Population thematic layer with the following roof types: Flat, Gabled, Curved, Circular with Flat Roof, Sawtooth, Gabled (pitched).
9. The feature "Interchange" should have an attribute describing the type of interchange with the following possibilities: Cloverleaf, Diamond, Rotary, Turban, Fork, Wye, Trumpet, Symmetrical Ramps, Staggered Ramps.
10. The "Existence Category" under Road should have "Existence Reported" as an additional integer value.
11. The feature "Stadium" should have an attribute to describe the type of stadium (Enclosed, Open-Ended, Domed).
12. Towers in the DFAD specification are categorized according to their shape. An attribute needs to be added to "Tower (communication)," "Tower (non-communication)," and "Water Tower" to describe the shape of the tower with the following possible shapes: "A", "I", "H", "Y."
13. The following integer values should be added to the "Radio Navigation/Communication" attribute for NAVAIDS (Aeronautical):
    Radar Reflector - Unidirectional
    Radar Reflector - Bidirectional
    Radar Reflector - Omnidirectional
    Radar Antenna with Radome
    Radar Antenna - Tower Mounted with Radome
    Radar Antenna - Tower Mounted.
14. The feature "Tank" should have a "Structure Shape Category" attribute with the following integer values:
    Cylindrical - Flat Top
    Cylindrical - Dome Top
    Cylindrical - Peaked/Conical Top
    Cylindrical - Peaked/Conical Top - Tower Mounted
    Spherical
    Spherical with Column Support
    Blimp
    Bullet
    Telescoping Gas Holder (Gasometer).

15. The F_CODE scheme in both the high and medium resolution V_{Map} should be Feature and Attribute Coding Catalog (FACC) instead of Feature and Attribute Coding Standard.
16. A table of contents listing all of the tables and appropriate page numbers should be added to the beginning of the appendix section in the V_{Map} product specifications.
17. On page 3 of the high and medium resolution product specification documents under paragraph 2.1.2, "World Geodetic Survey 84 Technical Report" is listed as an applicable document. The citation should be more specific by giving the document number, edition number, and date of publication.
18. On page 5 of the high and medium resolution product specifications under paragraph 3.4, the following statement is made regarding Topographic Line Map product specifications: "Exceptions to the cartographic specifications may be found in the text of this specification." This statement should be more specific, citing the exceptions and where they can be found.

3.0 PROTOTYPE 2

The review of Prototype 2 is based on two areas, Texas and Bolivia, at two different resolutions, medium (1:250,000 map scale sources) and high (1:50,000 or 1:100,000 map scale sources). The respective libraries are named TEXASM, BOLIVAM, TEXASH, and BOLIVAH. Evaluations involved inspecting the written specifications for errors, finding areas of questionable accuracy in digitized data, and locating discrepancies between the written specifications and the libraries. Most of the evaluation was completed using VPFVIEW software. However, the BOLIVAM library was loaded in a RDBMS for further study.

A note on methodology is in order. For variety and brevity, the same types of evaluation were not consistently applied to each geographic area and level, e.g., a sample of features and attributes was reviewed on the Level 2 Texas area but not on the Level 1 Texas area. On the Level 1 Texas area, however, the library was evaluated with respect to digitizing and registration errors (i.e., "shifts" between coverages). To be complete, however, each geographic area and V_{Map} level was evaluated in some sense.

Also, at the time of this review, the lack of capability to import V_{Map} data (or any VPF product for that matter) into a GIS such as ARC/INFO prevented a more thorough evaluation.

3.1 Product Specifications

3.1.1 Content

According to V_{Map} product specifications, both Level 1 and Level 2 have two reference coverages and ten thematic coverages in the Data Library:

(1) Library Reference	(7) Industry
(2) Tile Reference	(8) Physiography
(3) Boundaries	(9) Population
(4) Data Quality	(10) Transportation
(5) Elevation	(11) Utilities
(6) Hydrography	(12) Vegetation

The Reference Library from prototype one was determined to contain one reference coverage and five thematic coverages (a new coverage, Library Reference, has been added since Prototype 1):

(1) Library Reference
(2) Database Reference
(3) Political Entities
(4) Tile Index
(5) Map Reference
(6) Place Names

In addition to the fact that the two levels are based on different resolutions, Level 1 coverages differ from the corresponding Level 2 coverages in that the number of feature classes available may differ, as evident in Table 2. Naturally, Level 2, its source being high resolution maps, has the greater number of features available. Only three features appear in Level 1 and not in Level 2, namely Convention Line/Mandate Line (Boundaries), Magnetic Disturbance Area (Boundaries), and Lagoon/Reef Pool (Hydrography).

Table 2. Feature Differences between Level 1 and Level 2 (FACC Codes precede feature name)

Thematic Layer	Feature	Level
Boundaries	FA050 Convention Line/Mandate Line	Level 1 only
	ZC040 Magnetic Disturbance Area	Level 1 only
	ZB030 Boundary Monument	Level 2 only

Thematic Layer	Feature	Level
Hydrography	BH190 Lagoon/Reef Pool	Level 1 only
	BD100 Pile/Piling/Post	Level 2 only
	BD130 Rock	Level 2 only
	BI040 Sluice Gate	Level 2 only
Industry	AB010 Wrecking Yard/Scrap Yard	Level 2 only
	AC020 Catalytic Cracker	Level 2 only
	AJ030 Feedlot/Stockyard/Holding Pen	Level 2 only
	AM010 Depot (Storage)	Level 2 only
	AM060 Storage Bunker/Storage Mound	Level 2 only
Physiography	DB180 Volcano	Level 2 only
Population	AI020 Mobile Home/Mobile Home Park	Level 2 only
	AK030 Amusement Park	Level 2 only
	AK040 Athletic Field	Level 2 only
	AK060 Camp	Level 2 only
	AK070 Drive-In Theater	Level 2 only
	AK090 Fairgrounds	Level 2 only
	AK100 Golf Course	Level 2 only
	AK170 Swimming Pool	Level 2 only
	AK180 Zoo/Safari Park	Level 2 only
	AL030 Cemetery	Level 2 only
	AL170 Plaza/City Square	Level 2 only
Transportation	AL060 Dragon Teeth	Level 2 only
	AN075 Railroad Turntable	Level 2 only
	AQ065 Culvert	Level 2 only
	AQ140 Vehicle Storage/Parking Area	Level 2 only

Thematic Layer	Feature	Level
	BB010 Anchorage	Level 2 only
	BB090 Drydock	Level 2 only
	BB240 Slipway/Patent Slip	Level 2 only
	GB015 Apron/Hardstand	Level 2 only
	GB030 Helicopter Landing Pad	Level 2 only
	BG045 Overrun/Stopway	Level 2 only
	GB075 Taxiway	Level 2 only
Utilities	AD020 Solar Panels	Level 2 only
	AD030 Substation/Transformer Yard	Level 2 only
	AT050 Communication Building	Level 2 only
Vegetation	BH077 Hummock	Level 2 only
	EA020 Hedgerow	Level 2 only
	EA030 Nursery	Level 2 only
	EB020 Scrub/Brush	Level 2 only
	EC010 Bamboo/Cane	Level 2 only

3.1.2 Accuracy Requirements

According to the V_{Map} product specifications, absolute horizontal accuracy is expressed in terms of ground distances measured in meters. The information in Table 3, taken directly from the product specifications, gives the ground distance horizontal accuracy classes and circular error at 90% probability. Although these error limits may be acceptable, more information is required for Navy applications, i.e., which coverages and feature classes are included in which accuracy categories.

The same can be said of vertical accuracy, which V_{Map} expresses at 90% probability linear error as a proportion of the contour interval (Table 4). Again, more detail is needed as to what coverages and feature classes the categories contain.

Table 3. Horizontal Accuracy (taken from product specifications)

Category	V_{Map} Level 1 (1:250,000)	V_{Map} Level 2 (1:50,000)	V_{Map} Level 2 (1:100,000)
1	125 m	25 m	50 m
2	250 m	50 m	100 m
3	500 m	100 m	200 m
4	>500 m	100 m*	>200 m

*appears exactly as in the specifications, but should probably be ">100m"

Table 4. Vertical Accuracy (taken from product specifications)

Category	V_{Map} Level 1 (Contour Interval)	V_{Map} Level 2 (Contour Vertical)
1	0.5	0.5
2	1.0	1.0
3	2.0	2.0
4	>2.0	>2.0

3.1.3 Modeling and Simulation Requirements

Since Level 2 has more features available than Level 1, as evident from Sec. 3.1.1, it was used in a survey that examined current and future needs of the modeling and simulation community. Participants were asked what features and attributes were necessary to meet their project's digital mapping, charting, and geodesy requirements. Those requirements that were *not met* in Level 2 are listed in Table 5. An important finding is that, of all coverages, Hydrography currently lacks the most requirements.

Table 5. Programs with Current and Future Requirements Not Met by V_{Map} Prototype 2 Level 2

Key

current requirement only

current and future requirement

future requirement only

FEATURE CLASS	FEATURES	ATTRIBUTES
ELEVATION	Regular Spaced Grid, Triangular Irregular Network, Irregular Network, Slope Polygon, Berm/Barricade, Ridge Line, Shaded Relief	Height Accuracy, Lineage, Location, Albedo, Emissivity, Radar Reflectivity, *Location Accuracy*, Min/Max/Medial Elevation, RMS Variability, Standard Deviation
TRANSPORTATION	Ramp, Distance Marker, Route Marker, Lighthouse, **DFAD Features**, Fueling Areas, *Subways*	Bridge Load Class, Under-Bridge Clearance, Slope, Orientation to North, Substructure Description (spans), Route Number, Lineage, Albedo, Emissivity, Radar Reflectivity, FLIP/DAFIF Information, **DFAD Attributes**, Location, *IR & NVG*
VEGETATION	Bog, Open/Meadow/Pasture, **DFAD Features**	Surface Material, Orientation to North, Subsurface Material, Wet, Open, Shrub, Summer % Density, Winter % Density, Spacing, Average Stem Diameter, Height Accuracy, Lineage, Albedo, Emissivity, Radar Reflectivity, **DFAD Attributes**, IR & NVG, *Radio Frequency*
HYDROGRAPHY	Underwater Cable, Shipping Channel, Inland Channel, Current/Flow Arrow, Tunnel/Bridge, Spoil/Disposal Area, Gridiron, Offshore Loading Facility, Maritime Station, Buoy, Electronic Beacon, Light/Lighthouse, Crib, Breaker, Anchorage Area, Pier, Wharf Area, Ship Repair Area/Dry Dock, **DFAD Features**	Left Bank Delineation, Right Bank Delineation, Left Bank Slope, Right Bank Slope, Subsurface Material, Velocity, Lineage, Albedo, Emissivity, Radar Reflectivity, Location, **DFAD Attributes, Position**, Riverine

FEATURE CLASS	FEATURES	ATTRIBUTES
POPULATED PLACE	none	Roof Type, Surface Material, Density of Roof Cover, Entrance/Exit, Window-Specific, Window-General, Interior Floor Plan, Address, Occupant, Height Accuracy, Lineage, Albedo, Emissivity, Radar Reflectivity, Building Traits, IR & NVG, Population, Location, *Size of Ext. Walls of Large Buildings*
INDUSTRY	Nuclear Accelerator, Blast Furnace	Roof Type, Surface Material, Orientation to North, Density of Roof Cover, Density of Tree Cover, Entrance/Exit, Windows-Specific, Windows-General, Interior Floor Plan, Address, Occupant, Albedo, Emissivity, Radar Reflectivity, Location, IR & NVG, Methods (nets, traps, etc.), *Cross-Section Areas*
SOIL	no soil feature class available	no soil feature class available
PHYSIOGRAPHY	Ridge Line	Height Accuracy, Lineage, Albedo, Emissivity, Radar Reflectivity, Location, Acoustic, Magnetic, Pressure, Age, IR & NVG, Thickness
UTILITY	Water Treatment Plant, Communication Nodes, Condensation Line, Railway, Steam Line, Telephone Station	Roof Type, Surface Material, Orientation to North, Density of Roof Cover, Density of Tree Cover, Entrance/Exit, Window-Specific, Window-General, Interior Floor Plan, Address, Occupant, Composition of Tower, Number of Cables in Conduit, Height Accuracy, Lineage, Albedo, Emissivity, Radar Reflectivity, IR & NVG, KVA, *Probability to Kill, Radar Cross Section*
BOUNDARY	Key Tracking Area, Restricted Airspace Boundary, Sensitivity Area, Software Boundary, Low Intensity Conflict Areas	Length, Width, Surface Material, Orientation to North, Height Accuracy, Albedo, Emissivity, Radar Reflectivity, Location, Acoustic/Magnetic/Pressure properties, Boundary Conditions (e.g., barbed-wire fence), Controller of Boundary

3.1.4 Errors and Recommendations

Listed below are general errors and recommendations on the written specifications:

- "Pier/Wharf" is the feature description on page 307 (Level 2), whereas the database displays the more descriptive "Pier/Wharf/Quay" on spatial queries.
- On page 312 (Level 2), attribute RST value 2 is titled "Loose," whereas in the database the value is further qualified as "Loose/unpaved."
- On page 319 (Level 2), the feature is listed as "Aircraft Facility," whereas in the database name "Airport/Airfield" is used.
- On page 345 (Level 2), the attribute NST is listed as "Radio Navigation/ Communication," but the database uses the more descriptive name "Navigation System Types."
- An appendix, listing in a straightforward manner, the full names of available feature classes, features, and attributes would be extremely helpful.

3.2 Implementation

This section deals exclusively with the data contained in the databases, without regard to the written specifications of V_{Map}. Important points to note here are digitization errors that are displayed in the accompanying figures, e.g., continuous operating railroads having "gaps" of at least one mile. Also, features having questionable classifications are discussed, e.g., grass/sod runways being classified as "Major Airfields."

3.2.1 Level 1

Examples of data errors contained in the medium resolution database of Texas are provided in the following figures. Figure 1 shows the results of a spatial query performed on an airport near the city of Waco. Hess runway, in the Transportation coverage, is described as operational, 822 m in length, with a grass/sod (soft) surface type. However, the associated airport, also in the Transportation coverage, is described as a Major Airfield, i.e., attribute APT, Airfield Type, is 1. In V_{Map} the possible values for APT are limited in the sense that "Minor Airfield" or a similar descriptive term is not a possibility. The only possible values for APT are 0 (Unknown), 1 (Major Airfield), 3 (Undefined Landing Area), and 9 (Heliport). (Note: According to the FACC, the value 2 for APT indicates a "Minor Airfield.")

Snapshot View

Spatial Query

```
ENTITY NODE 24:
Database: /cdrom/vmaplv1
Library: TEXASM
Coverage: TRANS
RUNWAYP.PFT: Runway Points Feature Table -
ID - Row ID: 11
F_CODE - FACC Code: GB055 (Runway)
AOO - Angle of Orientation (degrees): 999 (Unknown)
EXS - Existence Category: 28 (Operational)
LEN - Length/Diameter (meters): 822
NAM - Name: HESS
RST - Road/Runway Surface Type: 5 (Grass/Sod (Soft))
TILE_ID - Tile Reference ID: 7
END_ID - Primitive ID: 24
```

Spatial Query

```
ENTITY NODE 25:
Database: /cdrom/vmaplv1
Library: TEXASM
Coverage: TRANS
AEROFACP.PFT: Airport Facilities Points Feature Table -
ID - Row ID: 13
F_CODE - FACC Code: GB005 (Airport/Airfield)
APT - Airfield Type: 1 (Major Airfield)
COD - Certainty of Delineation: 2 (Limits and Info Unknown)
EXS - Existence Category: 28 (Operational)
NAM - Name: HESS
USE - Usage: 0 (Unknown)
ZV3 - Airfield/Aerodrome Elevation (meters): 165
TILE_ID - Tile Reference ID: 7
END_ID - Primitive ID: 25
```

Figure 1. Hess grass runway described as major airfield in VPFVIEW query

Figures 2a and 2b display an area near Waco and an associated railroad in the Transportation coverage. Unusually large "gaps" are present in the data and could be a result of faulty digitization. Data omission errors and improper registration are displayed in Figures 3 through 5. The circled items in Figure 3 show incomplete "pieces" of roads and data omissions of the railroad in places where a railroad and road are in close proximity. In Figure 4, water courses have clear data omissions. Figure 5 shows apparent shifts in geographical position between the Hydrography and Transportation coverages.

Figures 6a and 6b display water courses from the Hydrography coverage of the medium resolution Bolivia database. The Boundaries coverage political boundary line, between Bolivia and Brazil is determined by a river. This river is not recorded in the Hydrography coverage where one would expect, which caused some confusion. However, upon further study, the river was located in the *area* feature class Water Courses and Bodies in the Hydrography coverage.

Additional implementation deficiencies/suggestions are as follows:

- In the Boundaries coverage, the names of two countries should be incorporated as attributes NM3 and NM4 rather than the name of state and department.
- On political entities, a more desirable naming scheme would be as follows:

  NM3 = State, NM4 = Department, and NM5 = Country.

3.2.2 Level 2

Similar to the medium resolution case, the high resolution data of Texas had several digitization and registration problems. Figures 7a and 7b present one such example (Figure 7a gives the reference area). A railroad from the Transportation coverage is displayed, together with the feature class Roads in the city Killeen. This railroad (Name: Atchison Topeka and Santa Fe) is operational but has a "hole" in the data, as indicated in the figure. Additionally, some roads appear to be disconnected, which seems to indicate incomplete data.

Figure 8 displays the water courses in the Hydrography coverage and political boundaries in the Boundaries coverage of the high resolution Bolivia data. Similar to the Level 1 Bolivia database, confusion resulted near the boundary. Water courses appear incomplete, when in actuality the area feature class Water Courses and Bodies "fill-in" the gaps.

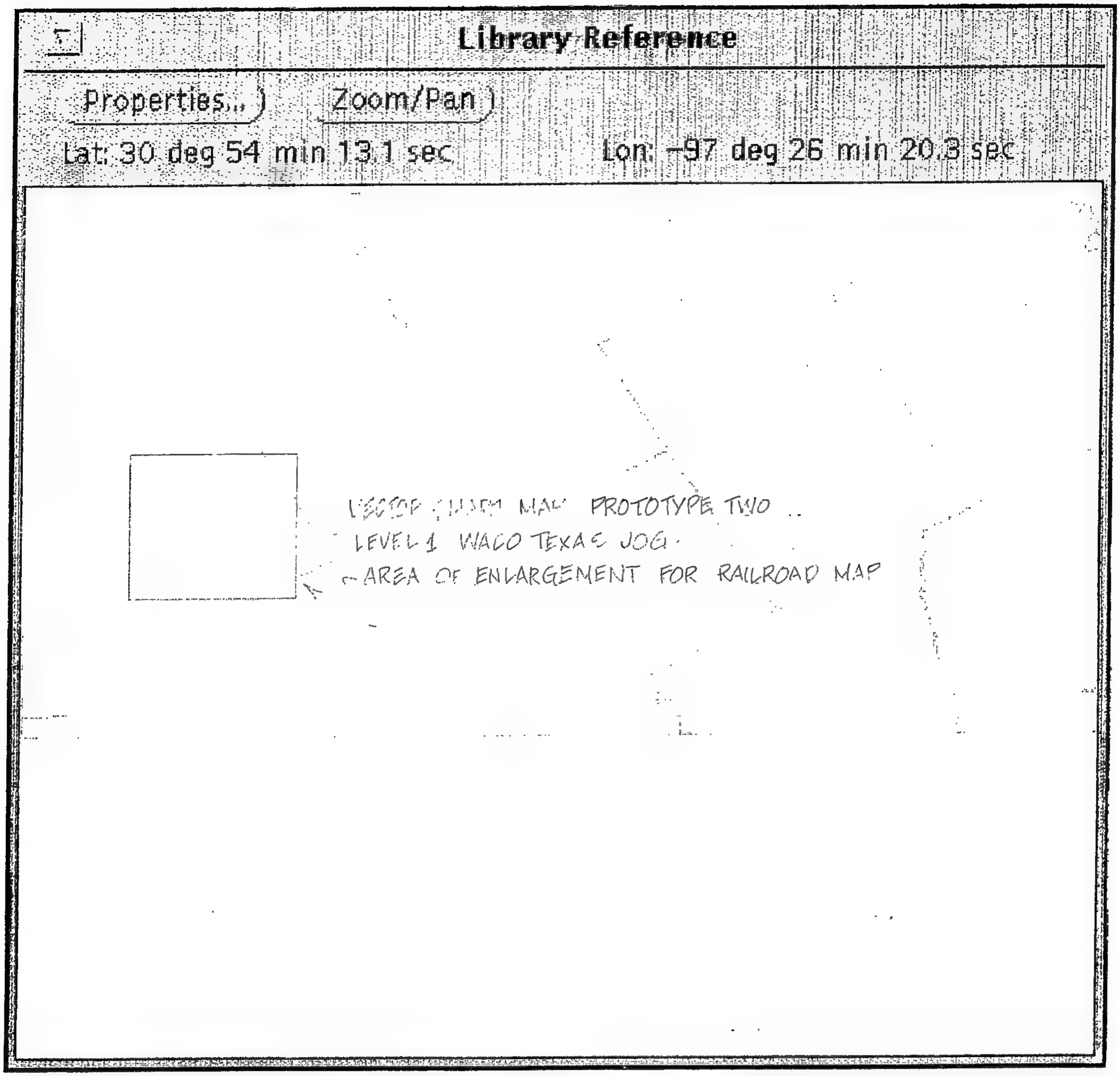

Figure 2a. Reference area for figure 2b railroad map

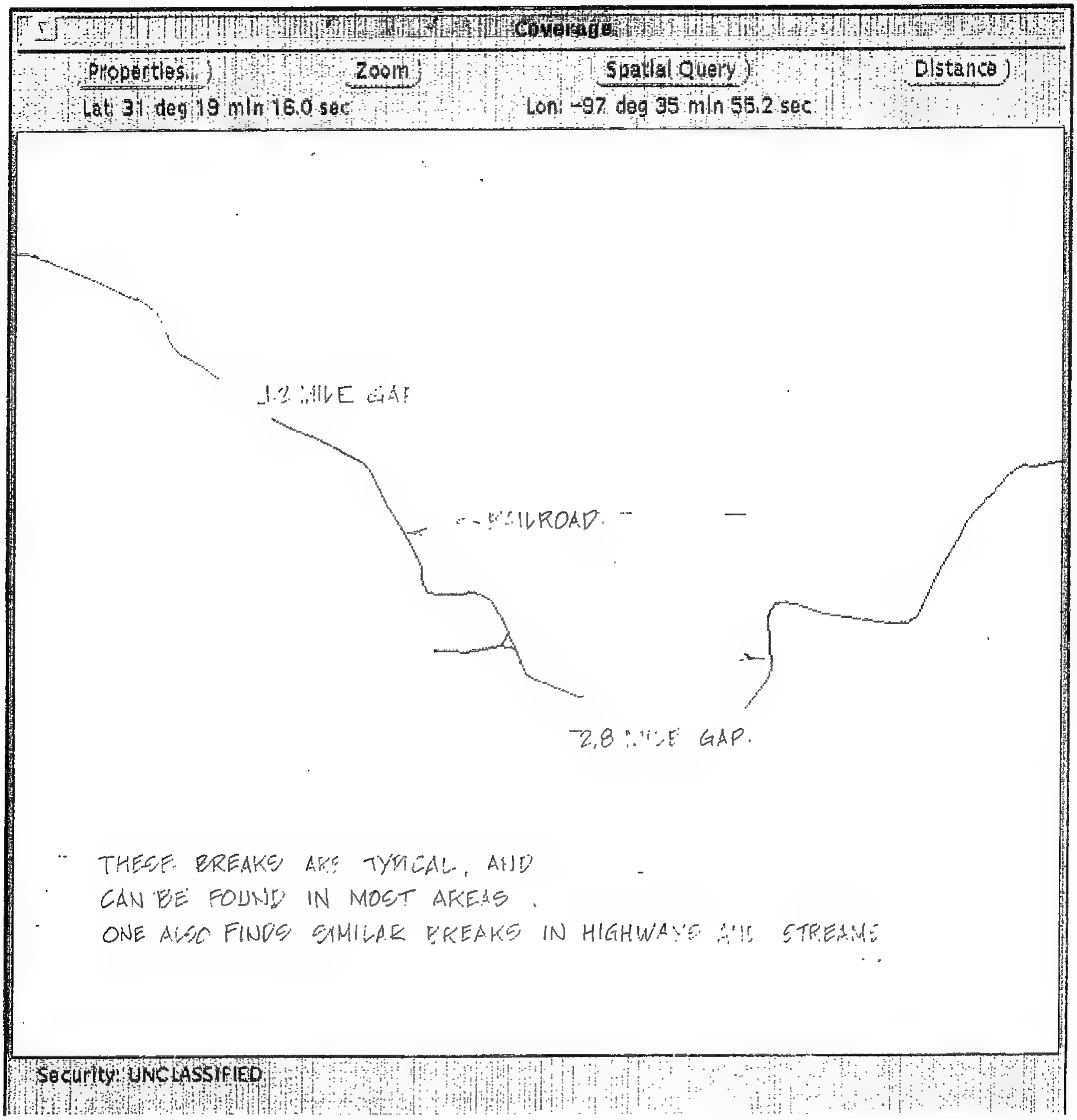

Figure 2b. Data content errors in railroad

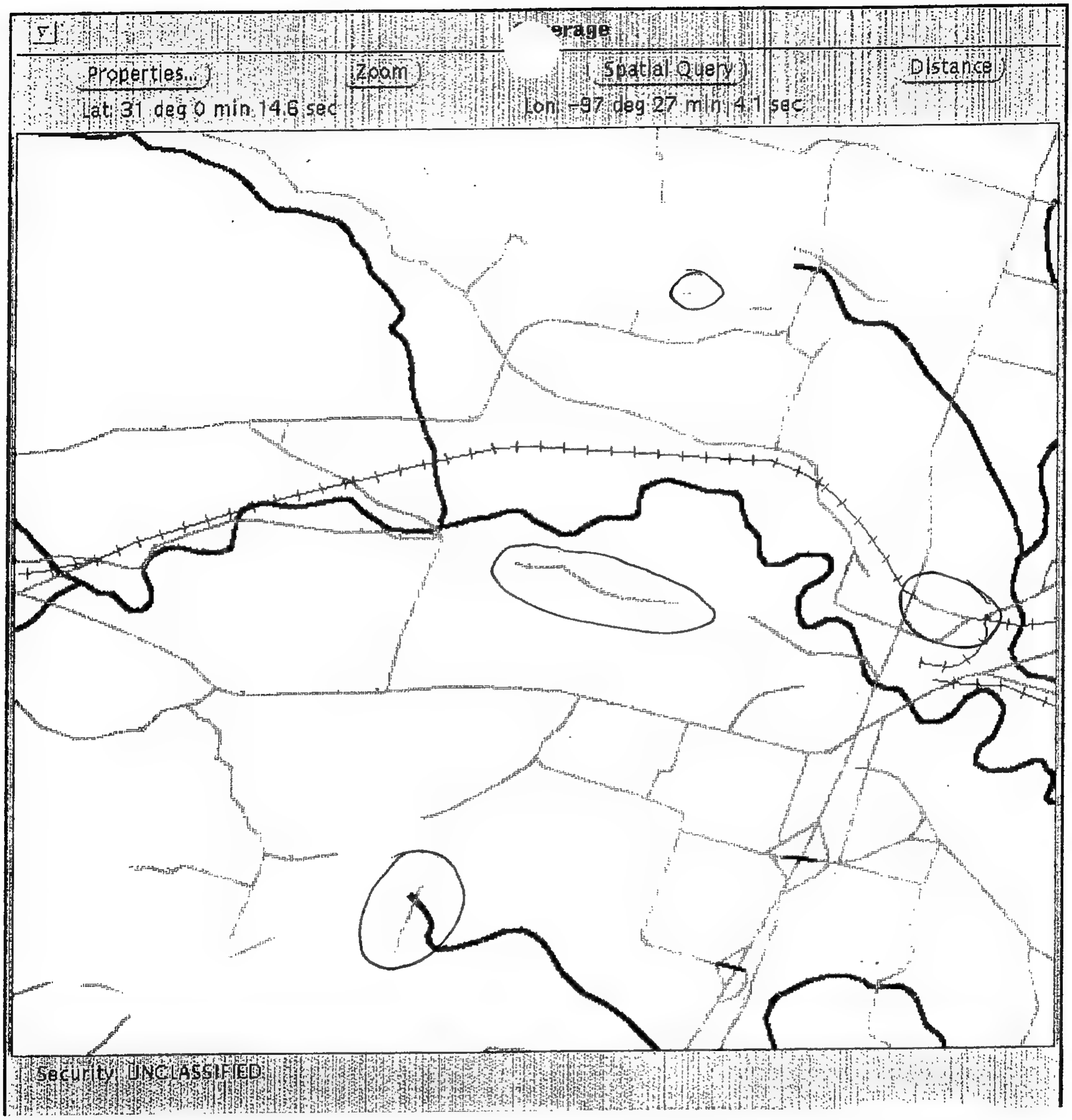

Figure 3. Incomplete roads and railroad data omissions

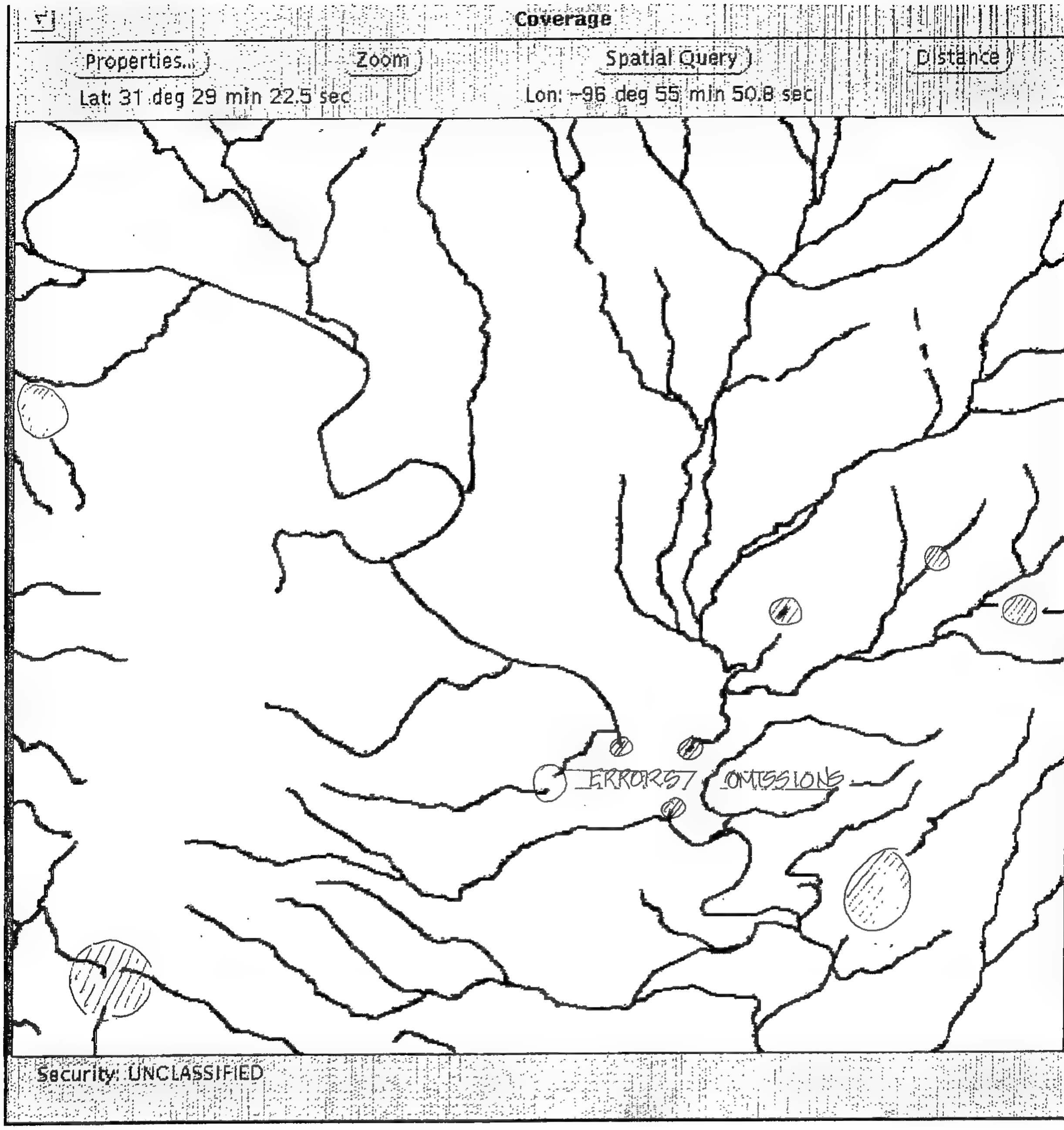

Figure 4. Data omissions in water courses

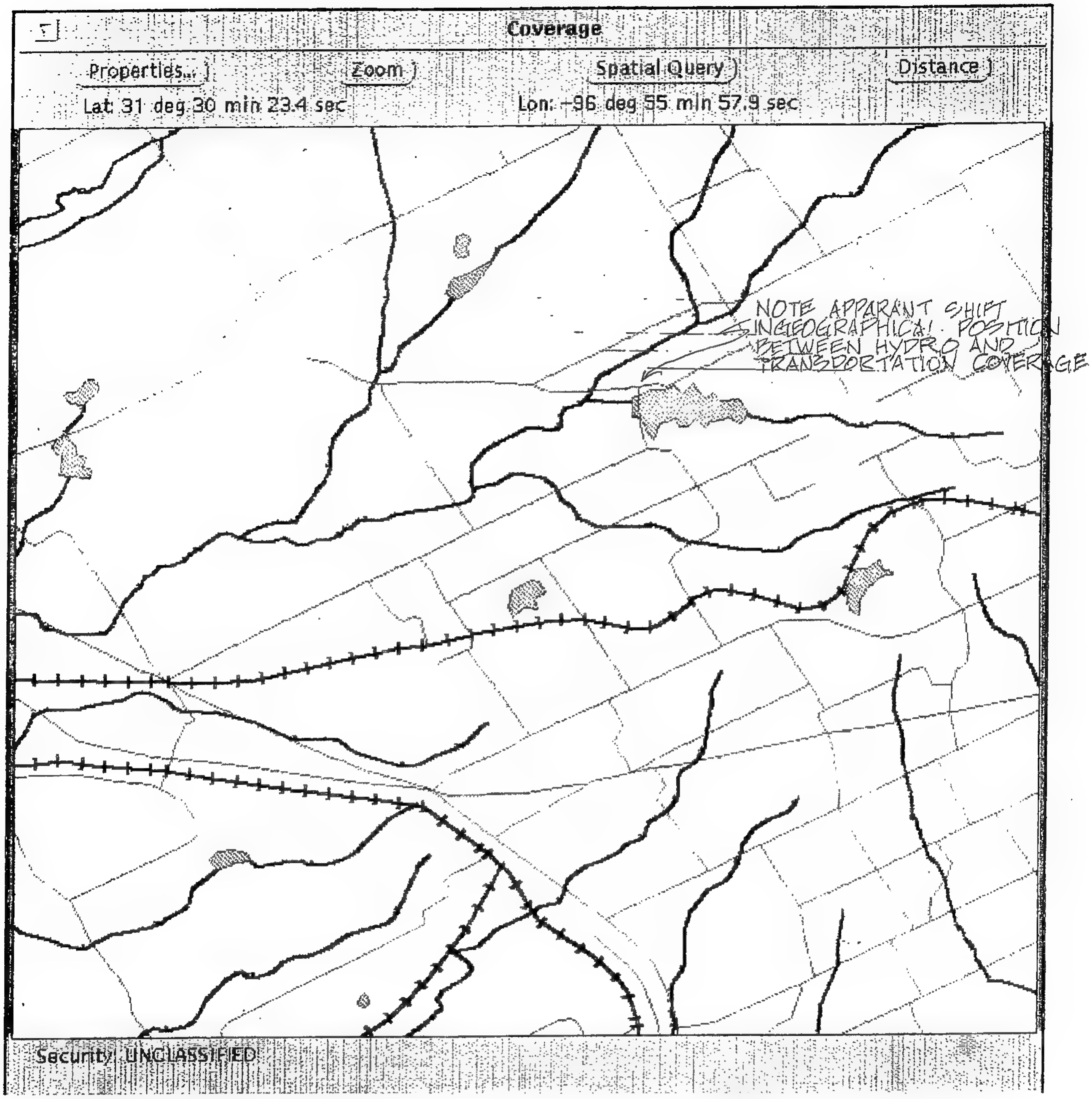

Figure 5. Shifts between hydrography coverage and transportation coverage

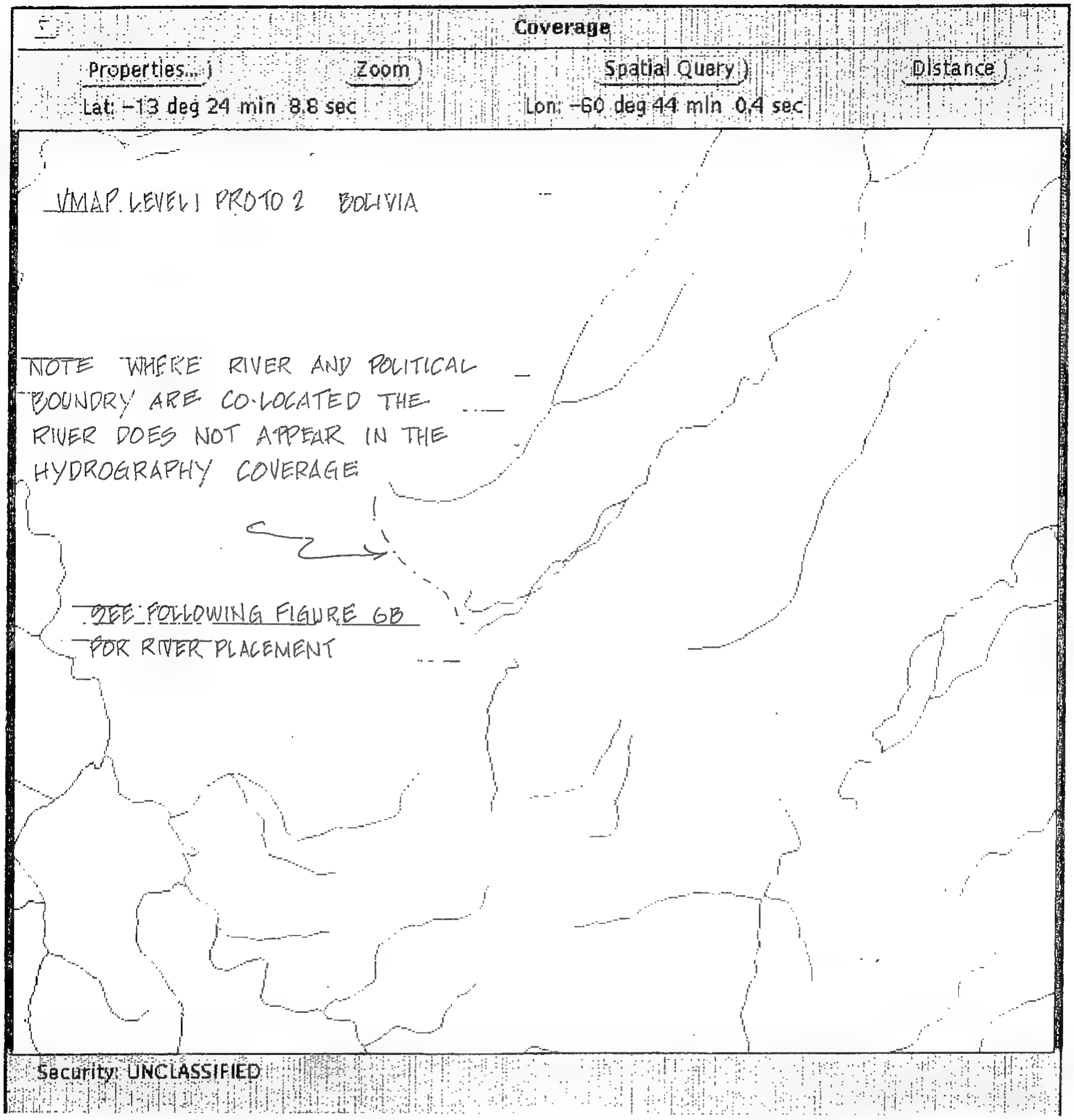

Figure 6a. "Missing" river/political boundary in hydrography coverage

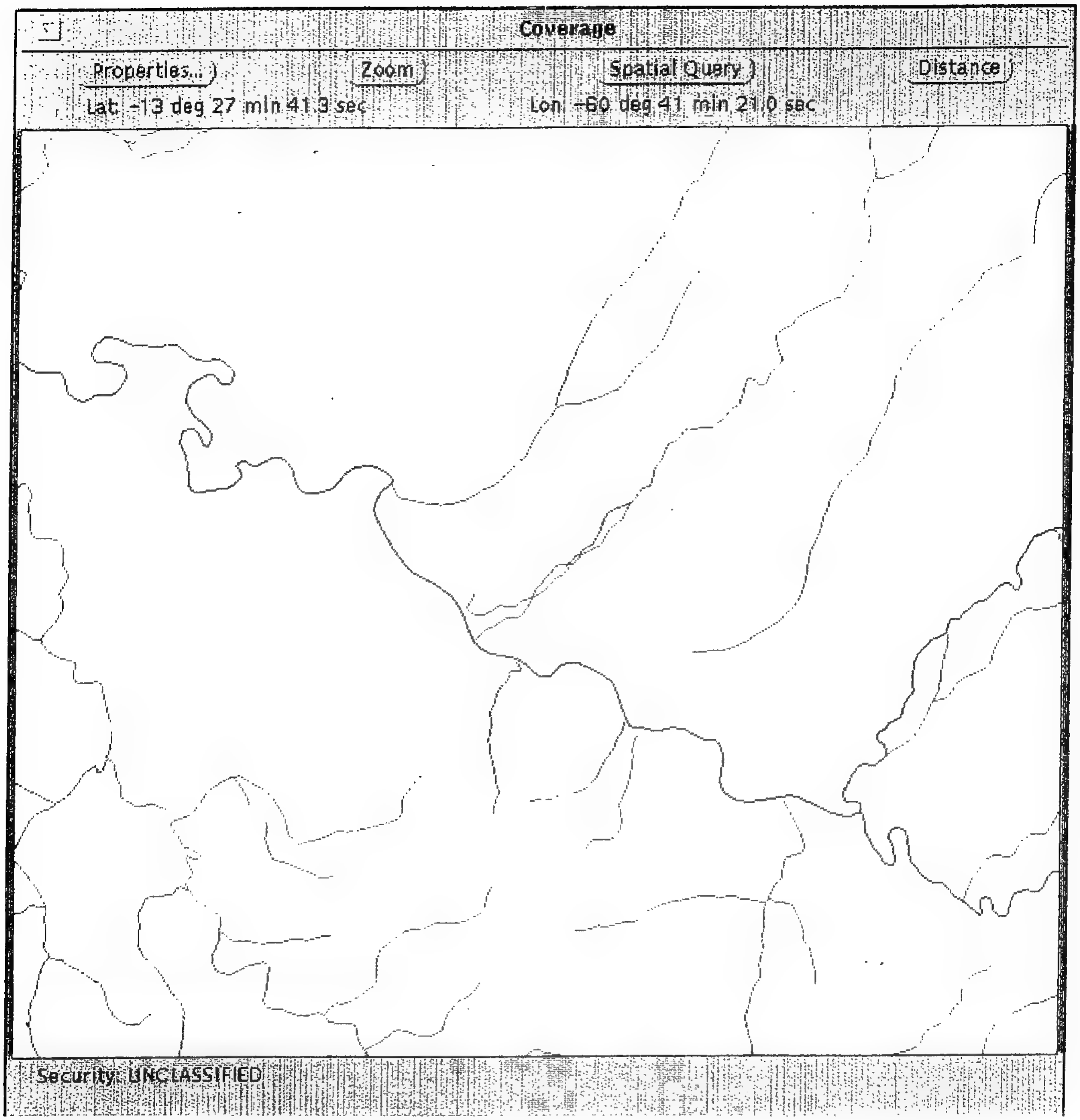

Figure 6b. Completed river/political boundary in hydrography coverage

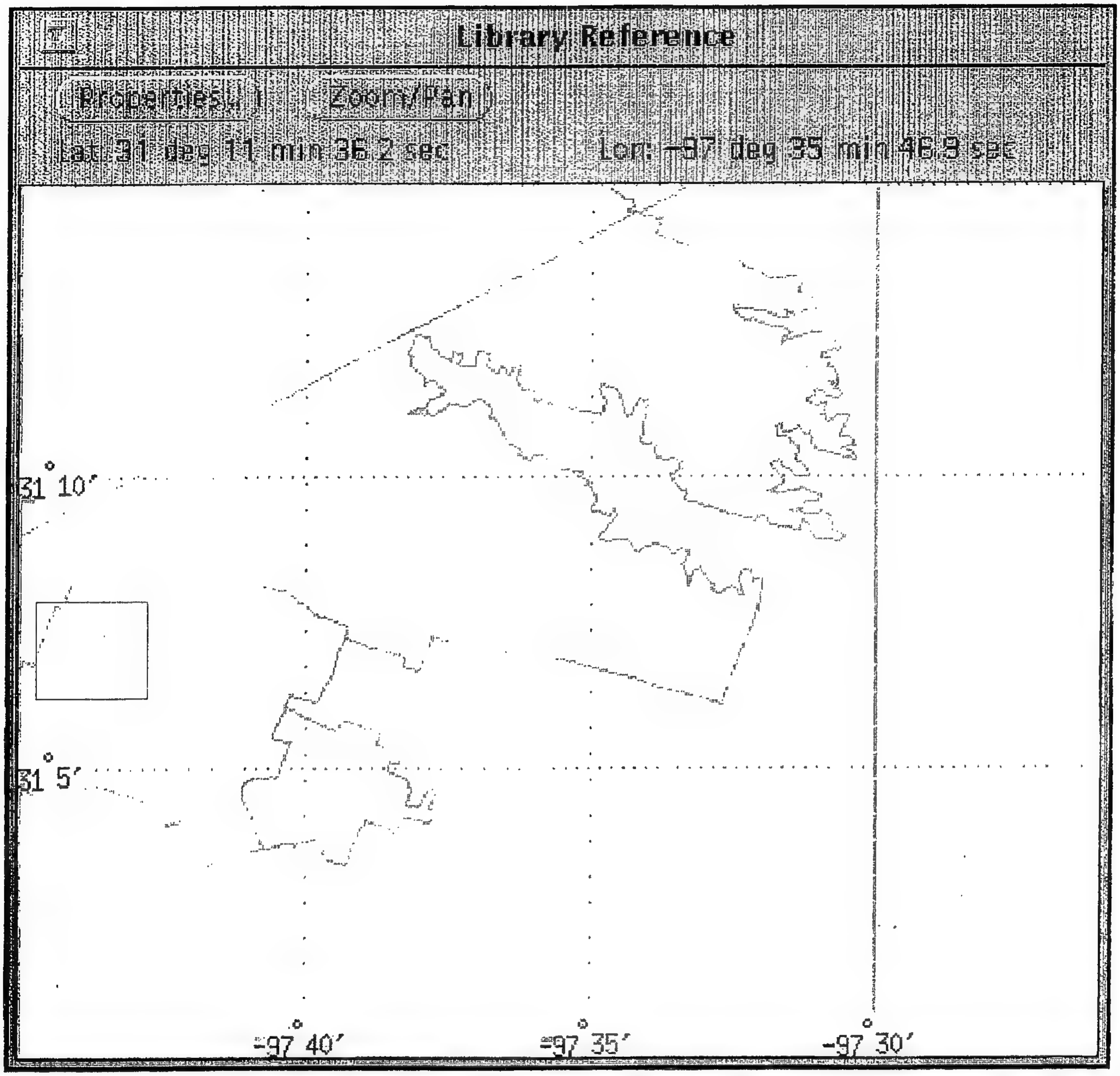

Figure 7a. Reference area for figure 7b road/railroad map

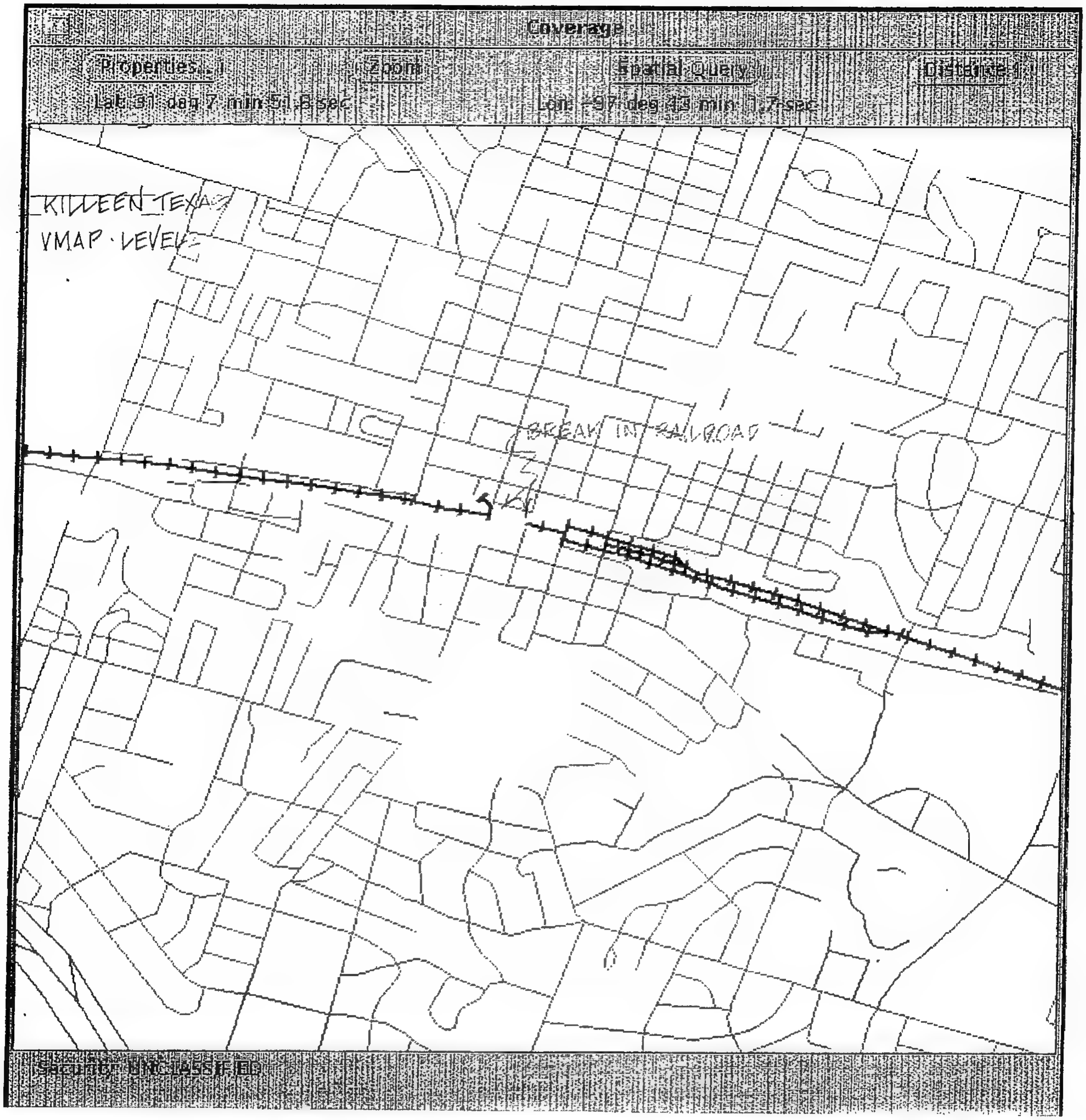

Figure 7b. Data content errors in roads/railroads

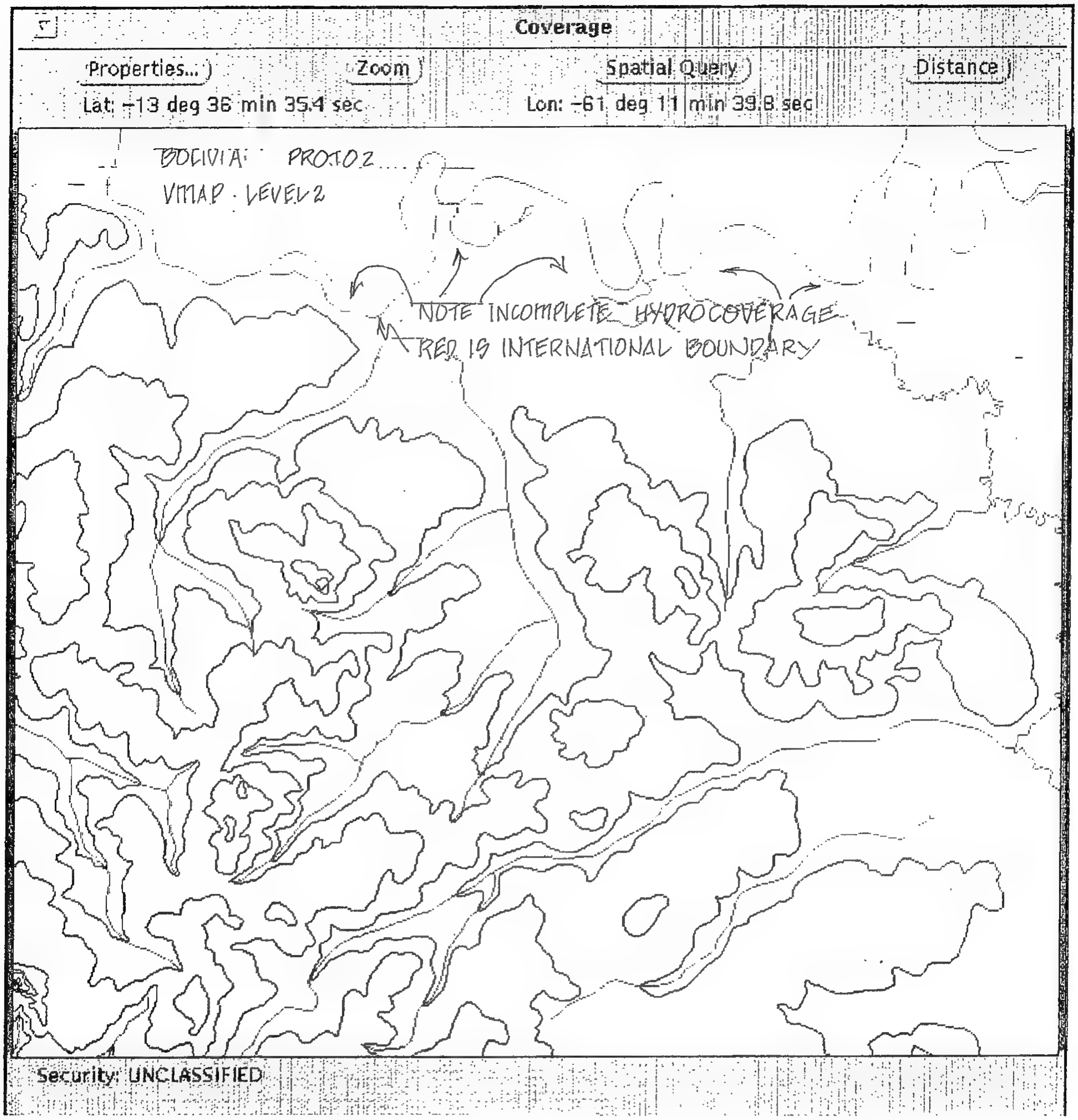

Figure 8 Water courses with apparent gaps

3.3 Discrepancies Between Product Specification and Implementation

In some instances during evaluation, the product specification and implementation provided conflicting information. For example, the product specification for Level 2 lists LEN (length) as an attribute of runway, but a VPFVIEW spatial query of a runway does not display LEN in the list of valid attributes. A more glaring omission from the database is the Data Quality coverage, which is listed in the product specifications.

3.3.1 Level 1

3.3.1.1 Texas

- The Data Quality coverage, as indicated in the specifications, is not in the database.
- In the Hydrography coverage, feature class Spring/Water Hole, EXS, PRO, and WFT are listed as attributes in the specifications, but do not appear in the database (specific example: NODE 1). Also, the NAM value is -9, which is not in the specifications.
- Also in the Hydrography coverage, feature class Dam Lines, NAM is missing on several features; EDGE 78 is one such example.
- In the Industry coverage, feature class Rigs and Wells, NODE 83 is missing attributes COE, HGT, LOC, NAM, and ZV2 in the data, but they are listed as valid in the specifications.
- In the Population coverage, feature class Building Points, attribute NAM is in the specifications; however, on several features NAM is missing. NODE 104 is one such example.
- In the Transportation coverage, feature class Railroad, EDGE 1699 is missing attribute LEN in the data, but LEN is valid according to the specifications.

3.3.1.2 Bolivia

- In the Data Quality coverage, the source information section has not been included in the feature table as per the written specifications.
- In the coverage Hydrography, feature class Water Courses, EDGES 12, 103, 203, and 150 are missing the NAM attribute, a valid attribute according to the written specifications.
- In coverage Hydrography, feature class Inundation Area, the units of measure are hectares according to product specifications, but the data displays units of square meters.

3.3.2 Level 2

3.3.2.1 Texas

Table 6 lists the default coverages and feature classes available in the Level 2 Texas database (Note: this list applies to Level 2 Texas data only). According to the product specifications, an additional thematic coverage, namely Data Quality, should be present in the Data Library level. This coverage is not present in this database.

Table 6. Coverages and Feature Classes available in the Level 2 Texas database

Coverage	Feature Class
Library Reference	Library Linear Features, Library Names
Tile Reference	Tile Extent
Boundaries	Markers, Political Boundaries, Administrative Areas
Elevation	Spot Elevation, Contour Lines
Hydrography	Wells and Springs, Aqueduct Lines, Dam Lines, Inland Shorelines, Water Courses, Dam Areas, Inundation Areas, Lakes and Reservoirs, Water Courses and Bodies
Industry	Mines/Quarries, Obstructions, Processing/Treatment Sites, Tanks and Water Tower Points, Noncommunication Towers, Disposal Areas, Processing/Treatment Plants
Physiography	Cut and Embankment Lines, Islands/Ground Surface Areas
Population	Building Points, Ruin Sites, Building Areas, Built-up Areas, Park Areas, Mobile Home, Sport Field Area
Transportation	Ford Sites, Bridge Lines, Pier Lines, Railroads and Sidings, Roads, Trails, Airport/Airfield, Runway Area
Utilities	Communication Points, Pumping Stations, Pipelines, Power Transmission Line, Telephone/Telegraph Lines
Vegetation	Grasslands, Orchards/Vineyards, Trees

As a test on specification/data agreement, four features, whenever possible, were randomly selected (e.g., four roads in the transportation coverage, or four building points in the population coverage) and a VPFVIEW spatial query was performed. The attributes that were displayed on the screen were then compared with those that were written in the specifications. The list in Table 7 gives specific instances where product specifications and Level 2 data disagree, the major results of which are itemized:

Table 7. Discrepancies between Level 2 Texas database and product specifications

Thematic Layer	Feature	Discrepancy
Boundaries	Markers	ENTITY NODES 8, 19, 32, 38 have NAM = -9, a value not in specifications
	Political Boundaries	EDGES 3, 6 have TXT = -9, a value not in specifications
	Administrative Areas	FACES 2, 4, 5 are missing NM4
Hydrography	Wells and Springs	NODE 1 is missing AOO
		NODE 2 is missing EXS, PRO, WFT
		NODE 2 has NAM = -0, a value not in specifications
	Dam Lines	EDGES 815, 904, 1050, 1112 are missing NAM
	Inland Shorelines	All sampled EDGES had shoreline type category "UNKNOWN"
	Water Courses	EDGES 106, 552, 1464, 1474 are missing NAM
	Lakes and Reservoirs	FACES 2, 3, 4, 5, 37 are missing EXS, NAM
		FACES 40, 43 are missing EXS
		FACES 6, 24 are missing HYC, SCC, ZV2
	Water Courses and Bodies	FACES 7, 8, 15, 21 are missing EXS, LEN, NAM
Industry	Mines/Quarries	NODES 4, 5, 6 are missing NAM
	Obstructions	NODES 1, 2 are missing LOC
	Processing/Treatme nt Sites	NODES 22, 23 are missing NAM
	Disposal Areas	FACES 13, 14, 15 are missing PRO
	Processing/Treatme nt Plants	FACE 6 is missing NAM
Physiography	Cut and Embankment Lines	EDGES 7, 9, 15, 17, 18 are missing HQC, PFD
	Islands/Ground Surface Areas	FACES 2, 3, 4, 5, 8, 11, 12 are missing ARA, MCC, NAM

Thematic Layer	Feature	Discrepancy
Population	Building Points	NODES 110, 261, 1951, 2629, 3277 are missing NAM (Note: most attribute values in these features indicated "UNKNOWN")
	Building Areas	FACES 72, 109 are missing NAM (Note: specifications state ARA measurements should be hectares, but the data is given in square meters)
	Built-up Areas	FACES 49, 51, 110, 122 have ARA units in square meters, specifications have hectares as the unit of measure
	Park Areas	FACES 57, 172 are missing EXS, USE
		FACE 69 is missing EXS
		FACE 78 is missing USE (Note: specifications state ARA measurements should be hectares, but the data is given in square meters)
	Mobile Home	FACES 121, 144, 153, 174 have ARA measurements in square meters, but specifications state the units as hectares
	Sport Field Area	FACES 73, 97, 108 are missing HGT, LEN, NAM, WID
		FACE 100 has NAM = -9, which is not a valid value according to specifications (Note: specifications state ARA measurements should be hectares, but the data is given in square meters)
Transportation	Roads	EDGES 129, 824, 5542, 2159, 2073 are missing NAM; also, WD1 is described as "Minimum traveled way width (decimeters)" in data and "Width of traveled way (meters)" in specifications
	Runway Area	FACES 16, 139, 358 are missing LEN
		Note: Many transportation attribute values indicated "UNKNOWN"
Utilities	Communication Points	ENTITY NODE 2 is missing LEN, NAM
Vegetation	Grasslands	FACES 207, 269, 504, 582 have ARA measurements in square meters, but specifications state that the units of measure should be hectares

Thematic Layer	Feature	Discrepancy
	Orchards/Vineyards	FACES 448, 451 have ARA measurements in square meters, but specifications state that the units of measure should be hectares
	Trees	FACES 2, 248, 439, 551 are missing NAM; also, ARA measurements are in square meters, but specifications state that the units of measure should be hectares

- NAM (Name) is an attribute that is associated with many feature classes. A "blank field" value, which indicates no name present for the feature, is a valid value for this attribute. However, many of these features lacked NAM when a spatial query was performed. Listing NAM in the data, followed by a "blank field" or the feature name as the specifications suggest, would leave no doubt as to whether or not the feature has a name.
- Hectares (10,000 square meters) are the units of measure for ARA (Area Coverage Attribute), according to the specifications. ARA values, however, are displayed in the data as simply square meters.
- In some occurrences of attributes NAM (Name) and TXT (Text Category) in the database, a value of -9 appears. This value has no definition in the product specifications.
- Many features have attributes listed in the specifications that do not occur in the database. In fact, most of the detailed list in Table 7 is comprised of these omissions. Some of the more frequently omitted attributes that clearly should be included are NAM (Name), EXS (Existence Category), LEN (Length), and PRO (Product).
- Some attribute names are conflicting between specification and database, which could cause confusion, e.g., NST is defined in the specifications as "Radio Navigation/ Communication," but the database shows "Navigation System Types." Another example is WD1, described in the specifications as "Width of Traveled Way (meters)" and "Minimum Travelled Way Width (decimeters)" in the data.

3.3.2.2 Bolivia

Major findings are as follows:

- In the coverage Boundaries, feature class Political Boundaries, EDGE 9 has a value of 0, but the meaning of this value ("UNKNOWN") is not displayed during a VPFVIEW spatial query (apparently "UNKNOWN" is not in the data).

- In the coverage Boundaries, feature class Political Boundaries, TXT has a value of -9 when a VPFVIEW spatial query is performed, which is not included as a valid value in the specifications.
- In the coverage Hydrography, feature class Lakes and Reservoirs, the specifications state ARA should have hectare units, but the measurement (according to VPFVIEW spatial query) is square meters.
- In the coverage Vegetation, feature class Trees, the specifications state ARA should have values $\geq 15,625$, but the data displays the questionable value -1,486,964,601 on spatial queries.

3.4 Microsoft Access and Level 1 Bolivia

Most evaluations of VPF data products are conducted using the VPFVIEW software. This evaluation attempted (with limited success) to import the VMAPLV1 BOLIVIAM data into the general purpose commercial RDBMS Microsoft Access (a commercial off-the-shelf (COTS) RDBMS. Microsoft Access is an IBM PC/Windows package.

3.4.1 Issues

- Georelational vs. relational: RDBMS theory requires all fields to be atomic in nature. Geographic products such as VPF use coordinate strings that do not fit into the relational model. For the purposes of this evaluation, the coordinate strings were not imported. In order to actually use VPF in a general purpose RDBMS, it would likely be most advantageous to maintain the coordinate strings outside of the RDBMS using custom software.

- Hierarchy: Most general purpose RDBMSs do not directly support the hierarchical nature of VPF. Microsoft Access does, however, allow the attachment of tables from other databases. The V_{Map} directory structure was duplicated and a Microsoft Access database was constructed at each level in the V_{Map} file system hierarchy. Each database was populated with the VPF tables that appeared in that directory in the V_{Map} product. For example, the top level directory VMAPLV1 contained one Microsoft Access database called VMAPLV1.MDB that contained LHT and DHT.

- Tiling: General purpose RDBMSs do not directly support the geographic concept of tiling. The hierarchical file system was used to allow tiles to be separate directories and databases.

- Table Import: The VPF tables were not directly importable into the RDBMS. Microsoft Access supports many import formats including the Windows clipboard, spreadsheet, dBASE, and many configurations of ASCII tables. It was necessary to devise a preprocessor program to convert the tables into an easily importable format. This program was constructed using the source code modules included with the VPFVIEW software. It reads in a single VPF table and writes it out as comma delimited ASCII files with the field names as the first row of data.

- Problems: Some tables became garbled during the translation to comma delimited ASCII. In particular, most of the feature tables failed to translate properly. Also, importing tables one-by-one was rather awkward and time consuming. This process should be automated to import an entire coverage, or a coverage restricted to a set of tiles. This type of general purpose utility should be provided by DMA under its MC&G Utility Software Environment (MUSE). It should be noted that such a program would support import into most all RDBMSs as they generally support import from comma delimited ASCII.

3.4.2 Results

Figure 9a shows the construction of a query using Microsoft Access Query By Example (QBE) editor. The query accesses a single table, the Inland Shore Line Feature Table in the Hydrography Coverage, and is designed to list the EDG_IDs that are in TILE_ID 8 that have a Shoreline Type Category of "Other" (attribute value 15). Figure 9b is the spreadsheet view of the result of the query. It was noted that all of the rows in this table have a value of "Other" in the Shoreline Type Category. If none of the shorelines fit any of the categories, then either the categories are poorly chosen or the data were carelessly produced.

Figure 10 is the Feature Class Schema (FCS) table for the Hydrography coverage. This table displays which tables may be joined on which fields to in effect produce larger "virtual tables."

The construction of a QBE query based on the information in the FCS is shown in Figure 11a. The SYMBOL_ID field in the HYDROTXT table can be joined to the SYMBOL_ID in the SYMBOL table to determine the font, style, size, and color to use to draw the text. Similarly, the TXT_ID field in the HYDROTXT table can be joined to the ID field in the TXT table to get IDs for the primitive and tile. The joins are created in QBE by simply dragging fields from one table to another. Figure 11b displays the Structured Query Language (SQL) generated by the QBE Editor for the query.

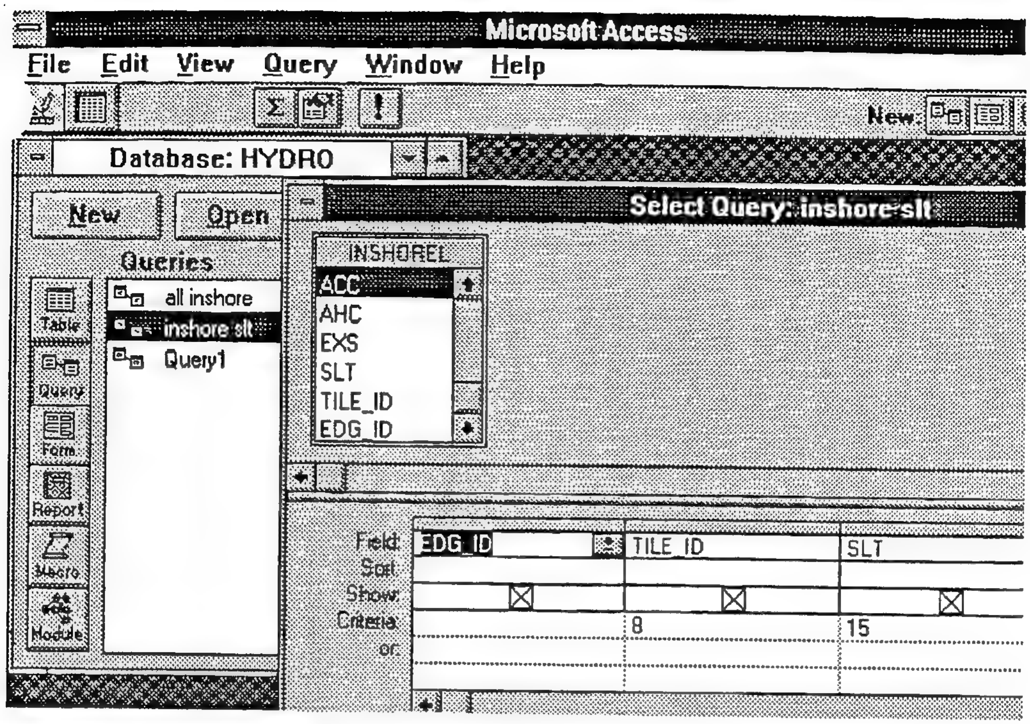

Figure 9a. Construction of a query using Microsoft Access QBE editor

EDG_ID	TILE_ID	SLT
190	8	15
192	8	15
204	8	15
212	8	15
227	8	15
229	8	15
233	8	15
234	8	15
239	8	15
245	8	15
250	8	15
256	8	15
275	8	15
286	8	15
293	8	15
295	8	15
303	8	15
305	8	15
307	8	15
308	8	15
312	8	15
321	8	15
325	8	15
340	8	15
345	8	15
352	8	15
355	8	15
356	8	15
361	8	15
363	8	15
364	8	15
365	8	15
372	8	15
376	8	15
377	8	15
381	8	15
394	8	15
395	8	15
398	8	15
407	8	15
427	8	15
449	8	15
450	8	15
451	8	15
456	8	15
459	8	15
472	8	15
473	8	15
476	8	15
477	8	15
480	8	15
490	8	15
491	8	15
493	8	15
494	8	15

Figure 9b. Spreadsheet view of the query in figure 9a

ID	F_CLASS	TABLE1	TABLE1_KEY	TABLE2	TABLE2_KEY
1	INSHOREL	INSHOREL.LFT	EDG_ID	EDG	ID
2	INSHOREL	EDG	INSHOREL.LFT_I	INSHOREL.LFT	ID
3	WATRCRSL	WATRCRSL.LFT	EDG_ID	EDG	ID
4	WATRCRSL	EDG	WATRCRSL.LFT_I	WATRCRSL.LFT	ID
5	INUNDA	INUNDA.AFT	FAC_ID	FAC	ID
6	INUNDA	FAC	INUNDA.AFT_ID	INUNDA.AFT	ID
7	LAKERESA	LAKERESA.AFT	FAC_ID	FAC	ID
8	LAKERESA	FAC	LAKERESA.AFT_I	LAKERESA.AFT	ID
9	WATRCRSA	WATRCRSA.AFT	FAC_ID	FAC	ID
10	WATRCRSA	FAC	WATRCRSA.AFT_	WATRCRSA.AFT	ID
11	HYDROTXT	HYDROTXT.TFT	TXT_ID	TXT	ID
12	HYDROTXT	TXT	HYDROTXT.TFT_I	HYDROTXT.TFT	ID
13	HYDROTXT	HYDROTXT.TFT	SYMBOL_ID	SYMBOL.RAT	SYMBOL_ID
14	HYDROTXT	SYMBOL.RAT	SYMBOL_ID	HYDROTXT.TFT	SYMBOL_ID

Figure 10. Feature Class Schema (FCS) table as shown by Microsoft Access

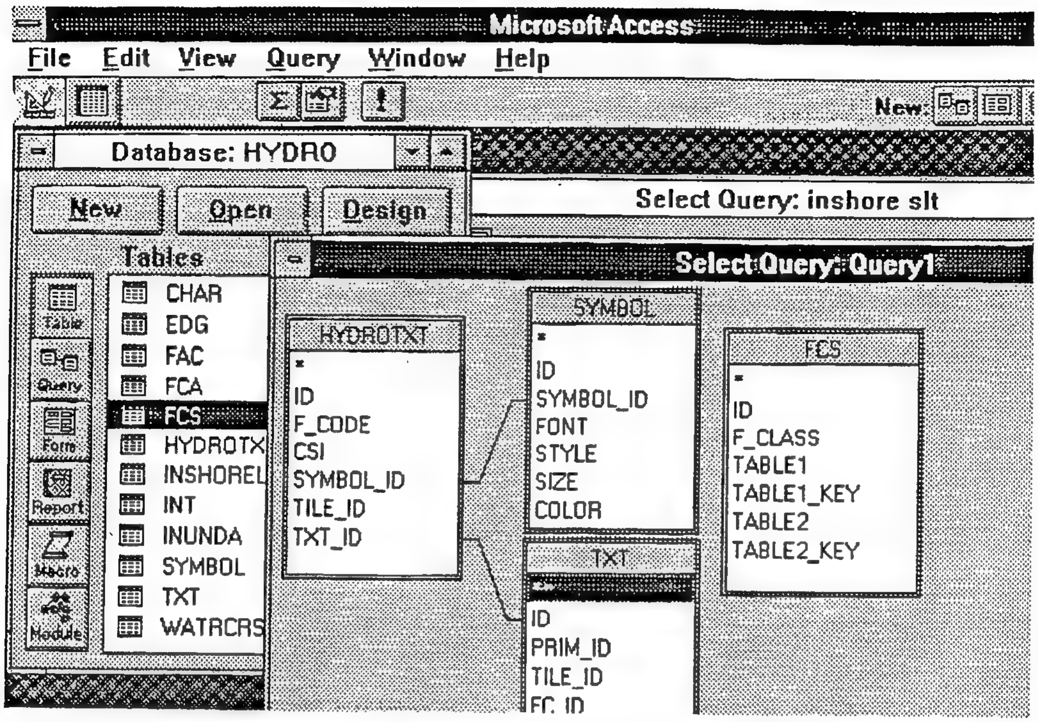

Figure 11a. Construction of QBE query based on FCS table

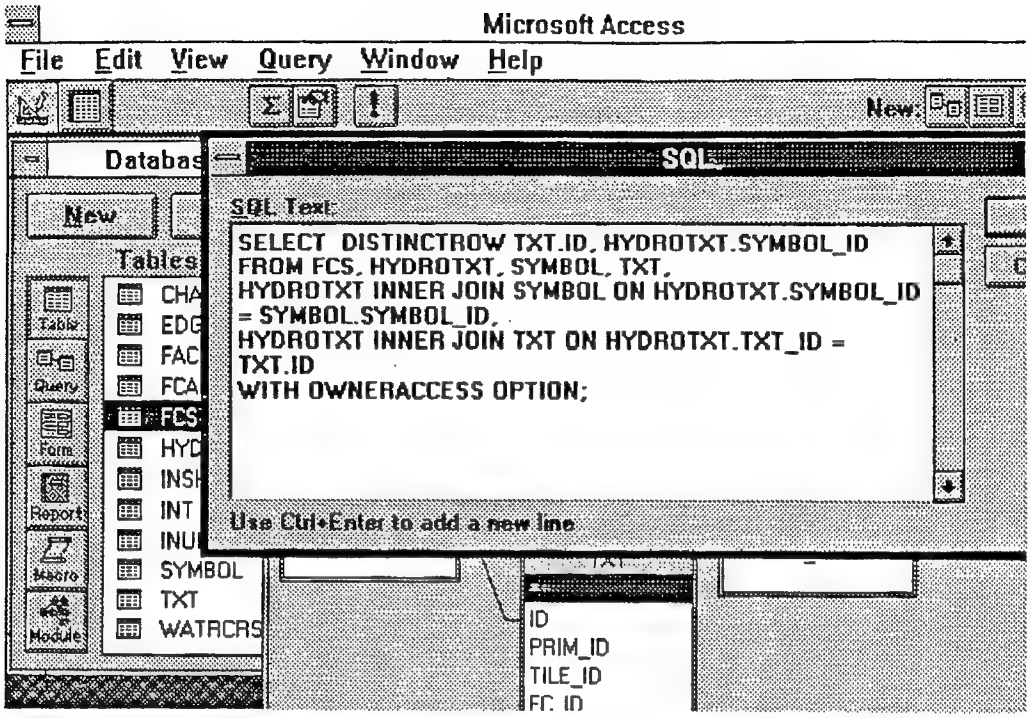

Figure 11b. Structured Query Language (SQL) generated for figure 11a query

3.4.3 *Conclusions on Microsoft Access*

- V_{Map} data can be imported into and queried within COTS RDBMSs.

- DMA should provide utilities to aid in interfacing data products to COTS software through MUSE.

- In the V_{Map} tables that were reviewed, "catch-all" attribute values such as "Other" seem to be overused.

3.5 Comparison of Interim Terrain Data and V_{Map} Level 2

In order to compare the data content and compatibility of Interim Terrain Data (ITD) and V_{Map}, the two databases were combined in a single view using VPFVIEW. The following figures show some of the results of this analysis.

Figure 12 is an overlay of the Built-up Area (AL020) features in ITD and V_{Map}. ITD is represented in yellow and V_{Map} in diagonal red stripes. As can be seen, the Built-up areas in ITD are more extensive than in V_{Map}. This may be due to the different levels of attribution in each database. In ITD, Built-up Area has no attributes, but in V_{Map} it can be categorized by density. All of the Built-up Areas appearing in V_{Map} are classified as "Dense." The following question arises: Will V_{Map} contain only "dense" Built-up Areas, or were these the only Built-up Areas digitized for this particular implementation of V_{Map}? In either case, assuming that ITD is correct, the remaining areas need to be added to V_{Map}.

In Figure 13, ITD Roads (AP030) are blue and V_{Map} Roads are red, ITD Bridges (AQ040) are green, and V_{Map} Bridges are black. In the bottom center of the figure, a road classified as paved and all weather is included in ITD and not shown on the hardcopy map, sheet 6446 II, series V782, edition 5-DMATC, Killeen. There are also smaller roads of all types scattered throughout the figure that are omitted from ITD. Finally, in the northwestern corner of the figure, three bridges are depicted by V_{Map}, while none are shown by ITD.

Figure 14 uses the same color scheme as Figure 13. In Figure 14 a section of highway is shown by ITD to have three bridges, but only one by V_{Map}. Also evident in this figure is the lack of agreement on the placement and shape of ITD and V_{Map} features. There is a constant offset between ITD and V_{Map} of .02 to .03 mi (106 to 158 feet) for all features in all coverages.

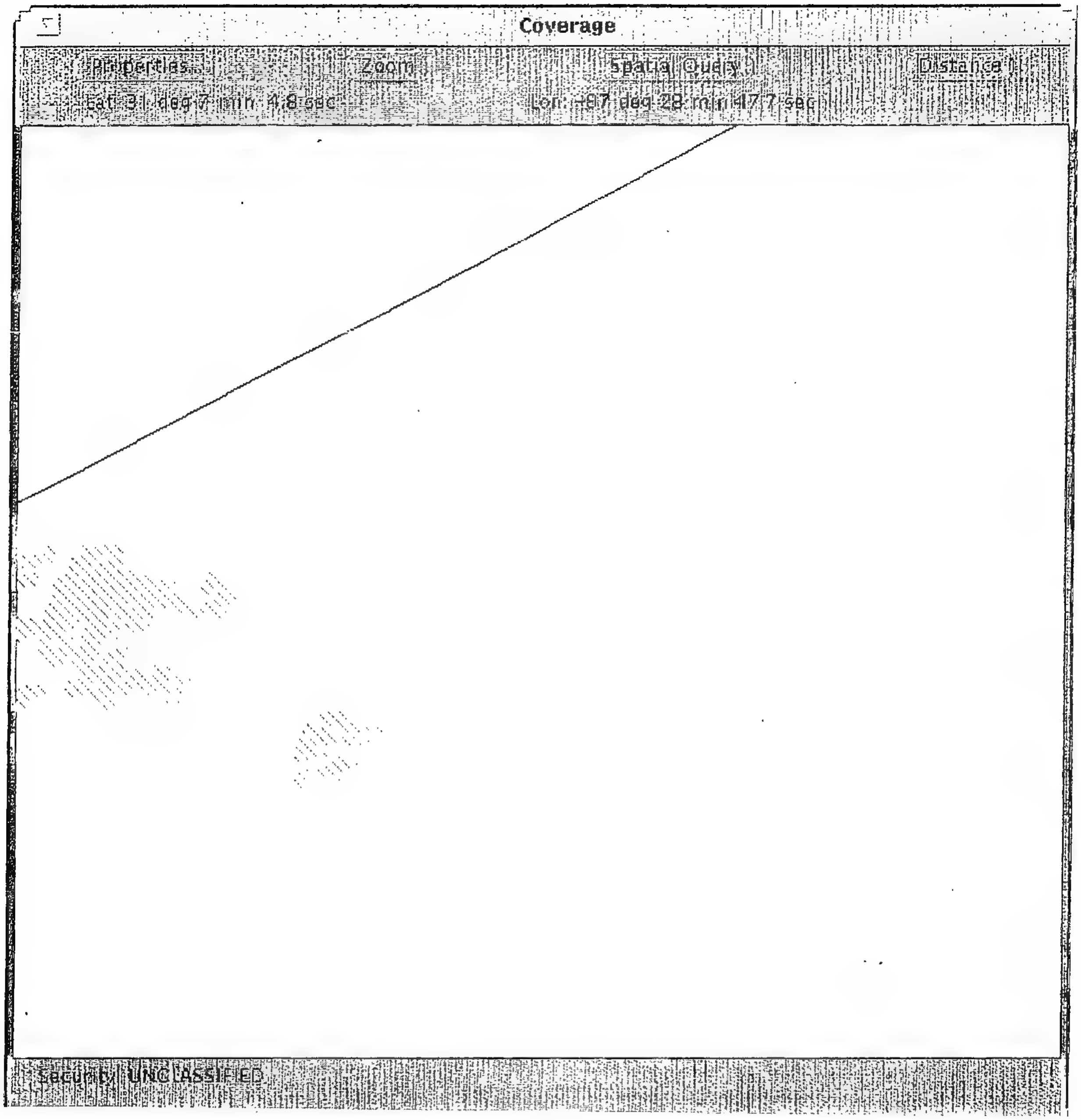

Figure 12. Overlay of V_{Map} and ITD built-up area features

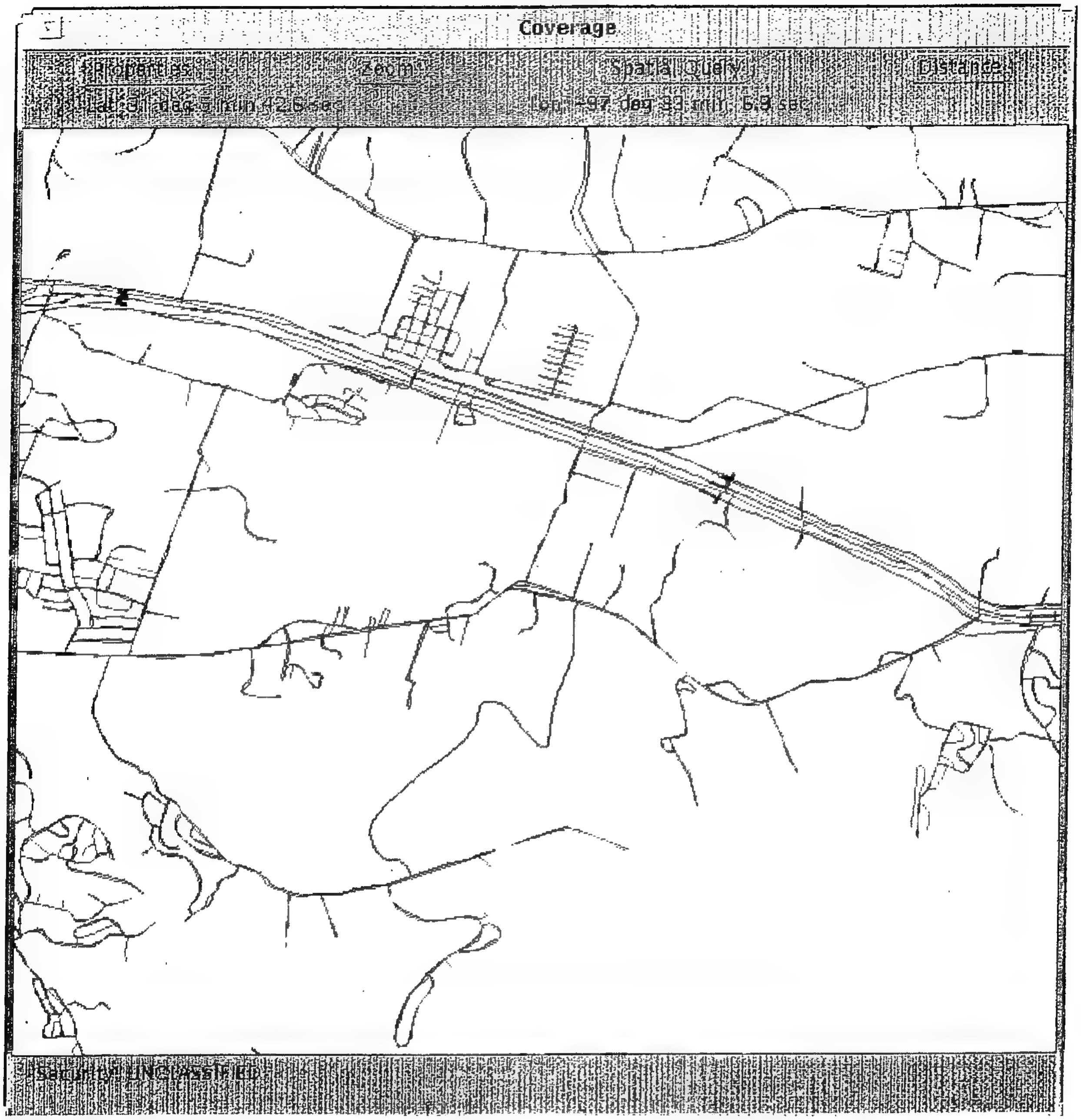

Figure 13. Road/bridge discrepancies among V_{Map}, ITD, and source map

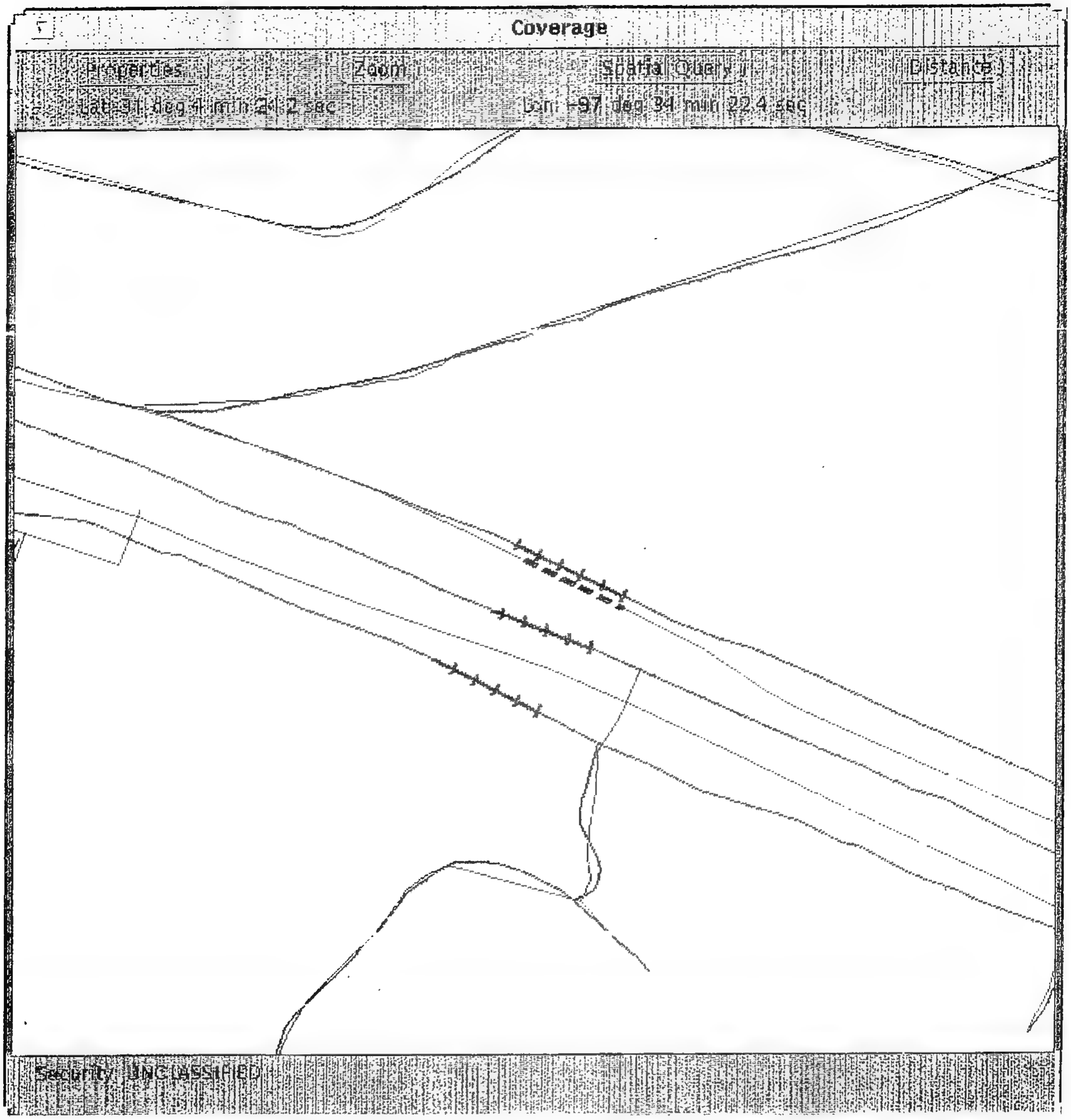

Figure 14. Road/bridge discrepancies between V_{Map} and ITD

Figure 15 shows ITD River/Stream (BH140) line features in blue, V_{Map} River/Stream line features in red, V_{Map} Lakes/Ponds (BH080) in blue, and ITD Common Open Water (SA010) in orange. Of importance in this figure are the small Lakes/Ponds that are omitted from ITD and the various small river branches that are included by one database and not the other.

In addition to the features and color scheme of Figure 15, Figure 16 includes ITD River/Stream area features in dark blue, V_{Map} River/Stream area features in red, and Reservoir (BH130) in medium blue. This figure shows a disagreement on the classification of the extreme western end of the reservoir. ITD classifies it as both a river line and area feature, while V_{Map} labels it an extension of the reservoir area feature.

Figure 17 shows ITD Rivers/Streams (BH140) in blue, V_{Map} Rivers/Streams in red, ITD Fords (BH070) in gold, and V_{Map} Fords in black. In this figure, there is disagreement between the number and location of fords in the figure. In addition, the ITD fords are not on the ITD river.

Figure 18 further shows the disagreement between the placement and number of fords.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Although Prototype 2 is a noticeable improvement over Prototype 1, shortcommings in the V_{Map} Level 1 and Level 2 products still exist. In Prototype 1, the majority of the deficiencies were in the form of missing features, such as those present in the DFAD product. In brief, DMAP recommendations were directed at bringing V_{Map} up to the standard of DFAD.

The flaws encountered in V_{Map} Prototype 2 were implementation errors and specification/data disagreements. The implementation errors involve poor registration among feature classes and apparently faulty digitization. For the most part, discrepancies between specifications and data took the form of attributes listed as valid according to the specifications, but missing from the database.

Several of the coverages, Hydrography, Transportation, and perhaps others, appear to have been generated by a color scan of a map source. While this technique may be a good beginning at generating segments, it leaves much to be desired in the area of completeness and topological connectedness. As the product now stands, the

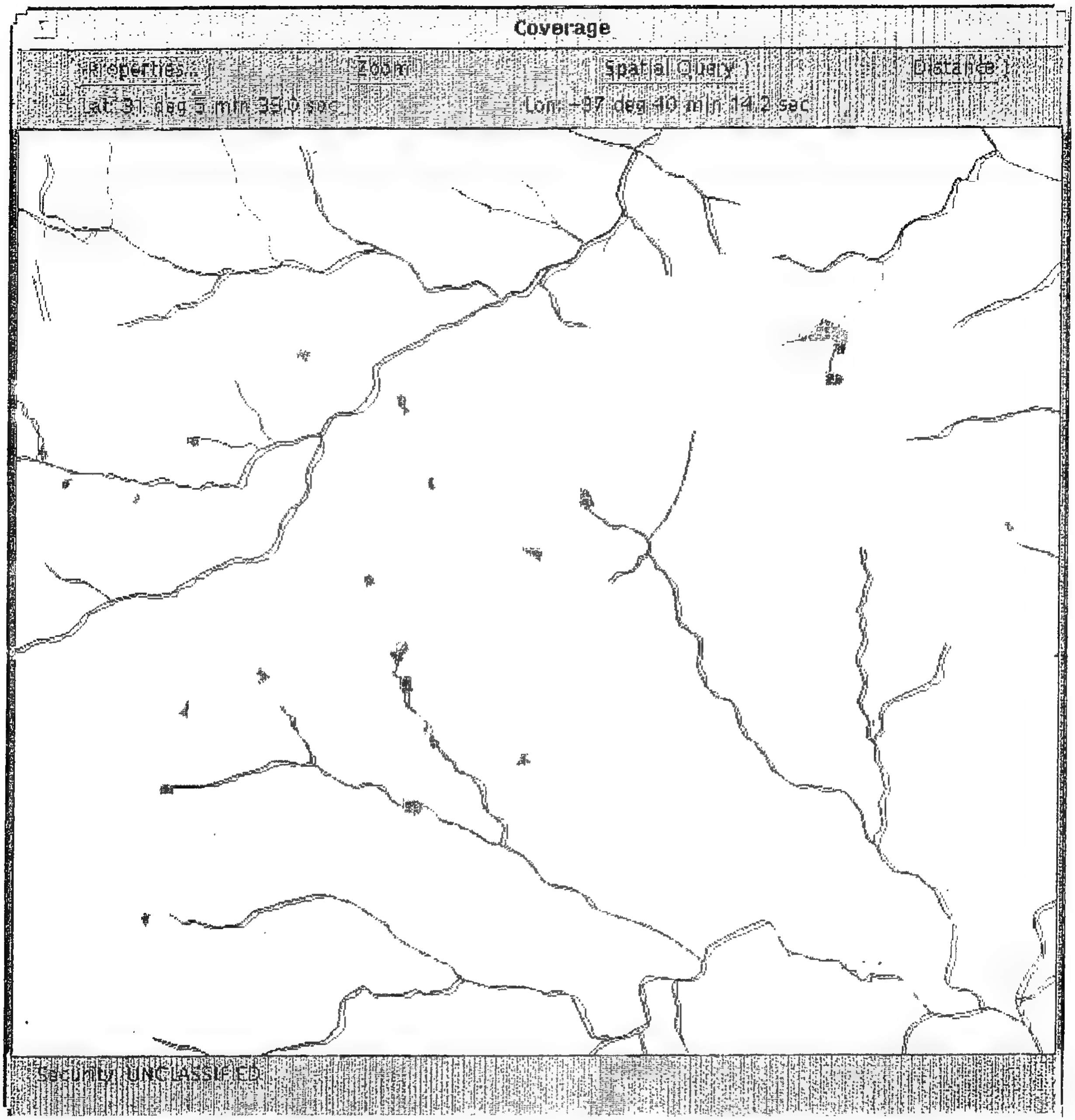

Figure 15. River/stream discrepancies between V_{Map} and ITD

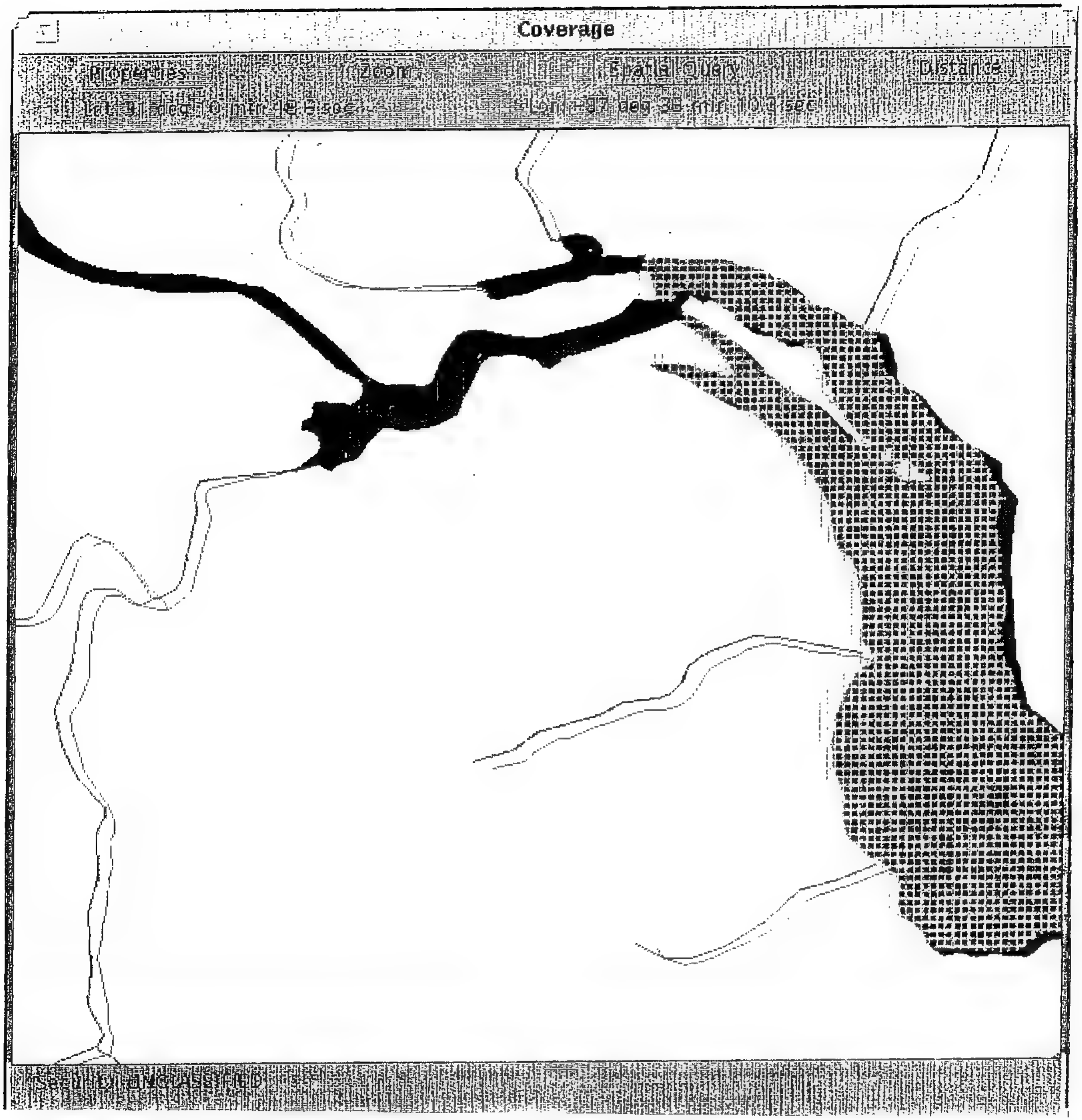

Figure 16. Reservoir classification disagreement between V_{Map} and ITD

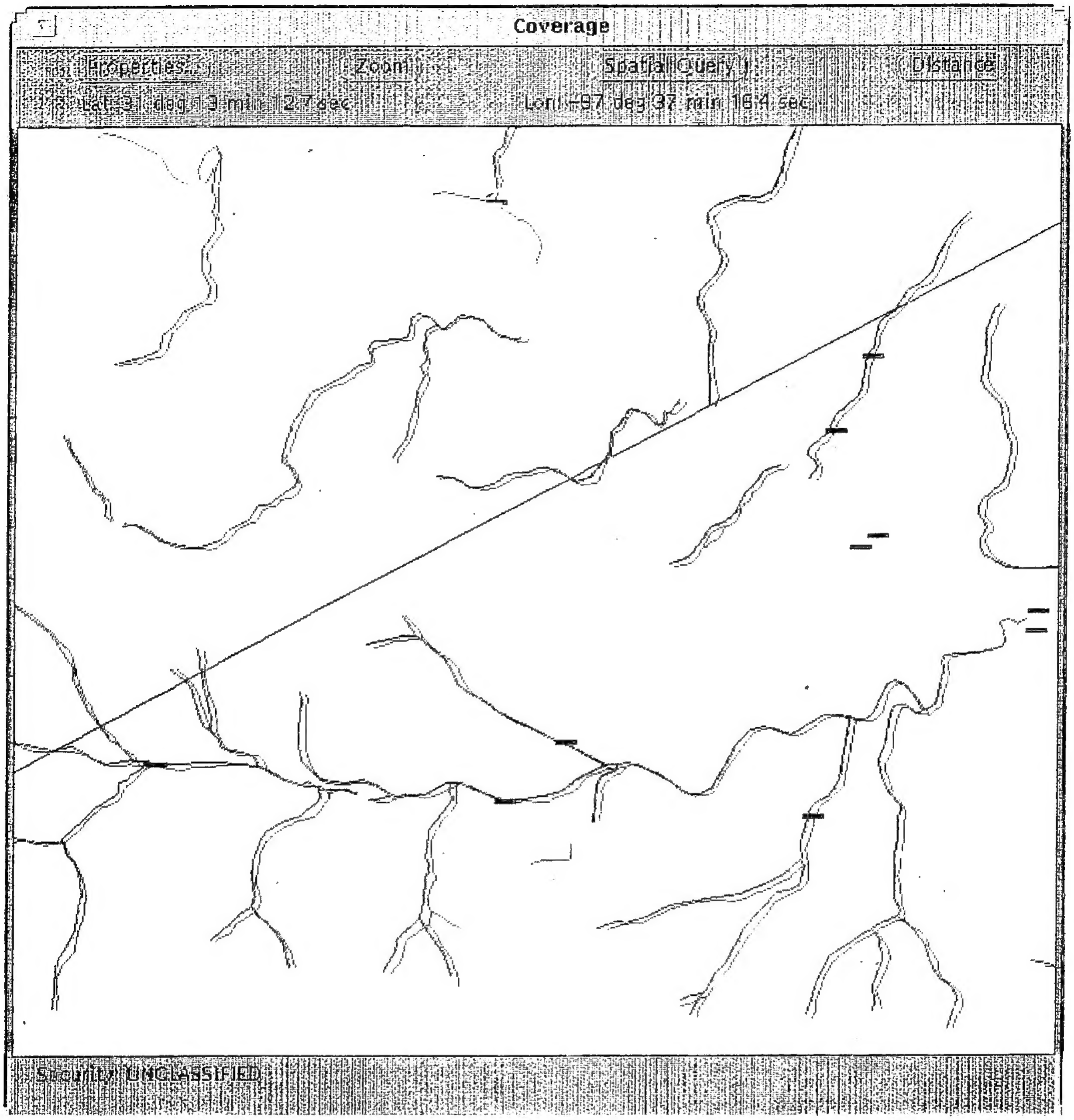

Figure 17. Ford differences between V_{Map} and ITD

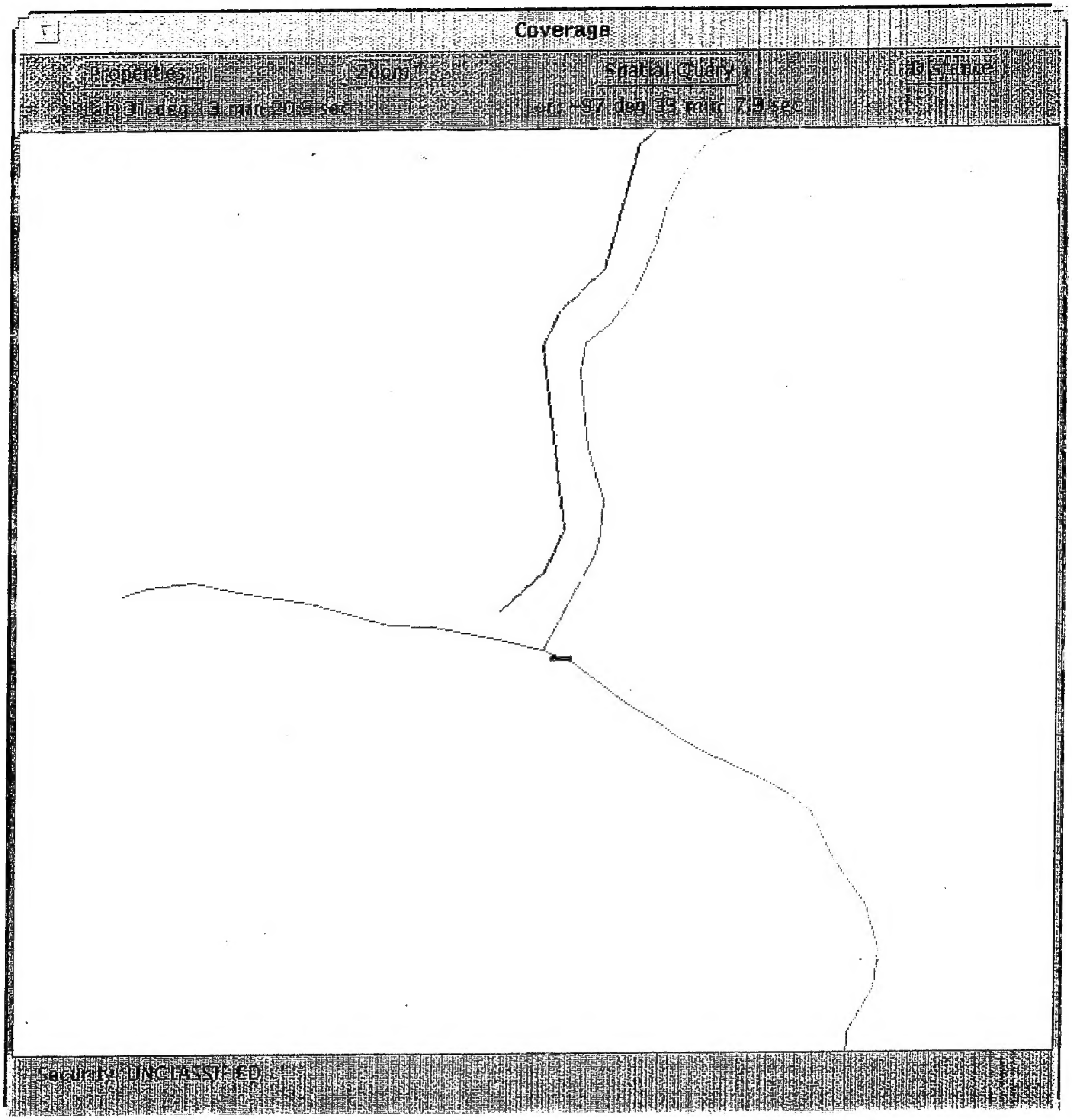

Figure 18. V_{Map} and ITD disagreement on placement and number of fords

linear features are of marginal use in many GIS applications. Another approach to coverage generation or extensive manual clean-up and editing is needed.

DMAP recommends that V_{Map} remain in the prototype stage until these issues are addressed.

5.0 ACKNOWLEDGMENTS

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3. Defense Mapping Agency, "Draft Military Specification Vector Smart Map (V_{Map}) Level 1," MIL-V-89033, 21 October 1992.

4. Defense Mapping Agency, "Draft Military Specification Vector Smart Map (V_{Map}) Level 2 Databases," MIL-V-89032, 28 January 1993.

APPENDIX. Acronym List.

ARA	Area Coverage Attribute
BOLIVIAH	Bolivia, High resolution library
BOLIVIAM	Bolivia, Medium resolution library
COTS	Commercial-Off-The-Shelf
CDROM	Compact Disc Read-Only Memory
DAFIF	Digital Aeronautical Flight Information File
DFAD	Digital Feature Analysis Data
DMA	Defense Mapping Agency
DMAP	Digital Mapping, Charting, and Geodesy Analysis Program
FACC	Feature and Attribute Coding Catalog
FACS	Feature Attribute Coding Standard
FCS	Feature Class Schema
FLIP	Flight Information Publication
GIS	Geographic Information System
IR	Infrared
ITD	Interim Terrain Data
kVA	kilo Volt-Ampere (complex power)
MC&G	Mapping, Charting, and Geodesy
MUSE	MC&G Utility Software Environment
NAVAIDS	Navigational Aids
NRL	Naval Research Laboratory
NVG	Night vision goggles
QBE	Query By Example
RDBMS	Relational Data Base Management System
SQL	Structured Query Language
TEXASH	Texas, high resolution
TEXASM	Texas, medium resolution
TLM	Topographic Line Map
TOWS	Tactical Oceanographic Warfare Support
USN	U.S. Navy
V_{Map}	Vector Smart Map
VPF	Vector Product Format
VSM	Vector Smart Map
WGS	World Geodetic Survey